Mass, Gas and Galaxies in the Abell 901/902 Supercluster

Catherine Heymans
on behalf of the STAGES collaboration
(PI: Meghan Gray)

University of British Columbia, Vancouver.
Canadian Institute for Theoretical Astrophysics, Toronto.
Institute d'Astrophysique de Paris.

STAGES

- 80 orbit mosaic
- ACS + WFPC2/NIC3 parallels
- science exploitation underway
- second largest HST mosaic
- sister survey to GEMS/ CDFS
- Data public 20th Feb 2008!

Collaborators

Nottingham
M Gray (PI)
K Lane
A Aragón-Salamanca
O Almaini
I Trujillo

Edinburgh
D Bacon
A Taylor

Oxford
C Wolf

Innsbruck
M Barden
E van Kampen

Texas
S Joghee
J Caldwell
F Barazza

HIA Victoria
C Peng

UBC
C Heymans
L Van Waerbeke

Arizona
C Papovitch

MPIA Heidelberg
HW Rix
E Bell
K Meisenheimer
R Somerville
S Koposov
K Jahnke
B Häußler
X Zheng
A Pasquali

UMass
D McIntosh

Columbia
B Johnson

AIP Postdam
L Witozski
A Boehm

CAHA
S Sanchez

ESO/Chile
R Gilmour

Waterloo
M Balogh

image: COMBO-17

Abell 901/902 Supercluster Dark Matter Map ▪ STAGES

Hubble Space Telescope ▪ ACS/WFC

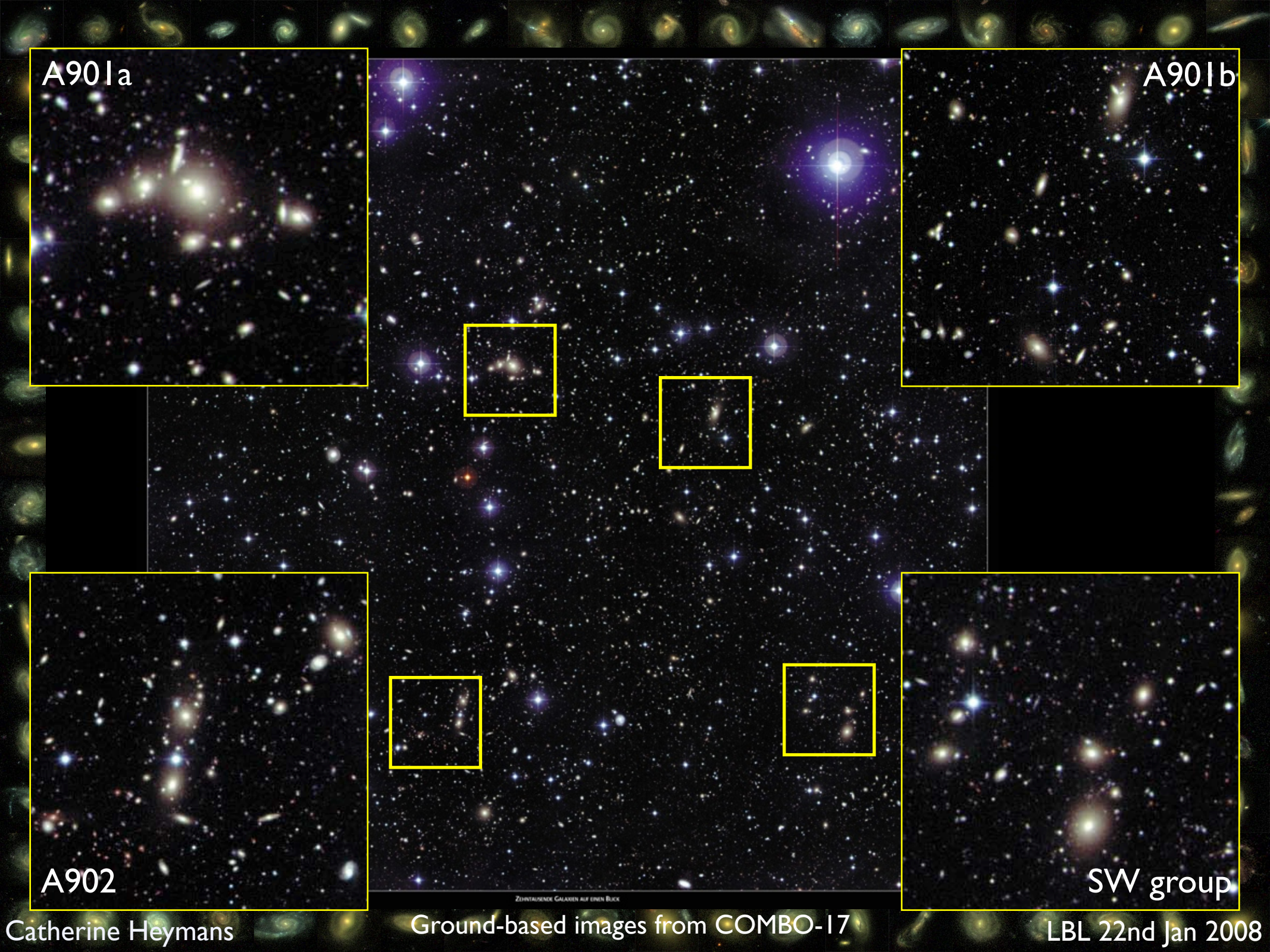
NASA, ESA, C. Heymans (University of British Columbia), M. Gray (University of Nottingham), and the STAGES Collaboration STScI-PRC08-03

Outline

- The STAGES survey
  - Galaxy evolution in dense environments
- "Seeing the invisible": mapping the dark matter environment of Abell 901/902
  - Weak gravitational lensing
- First galaxy evolution results from the Abell 901/902 laboratory

The Abell 901/902 Supercluster

30x30 arcmin image of the A901/2 supercluster at z=0.165

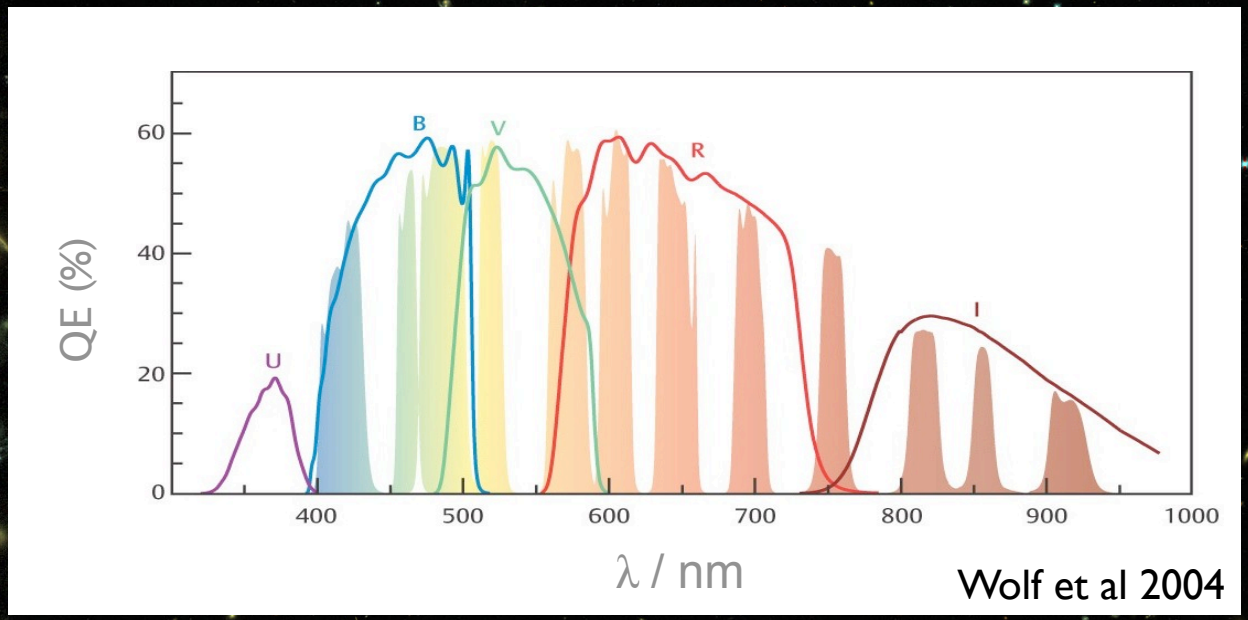


Catherine Heymans

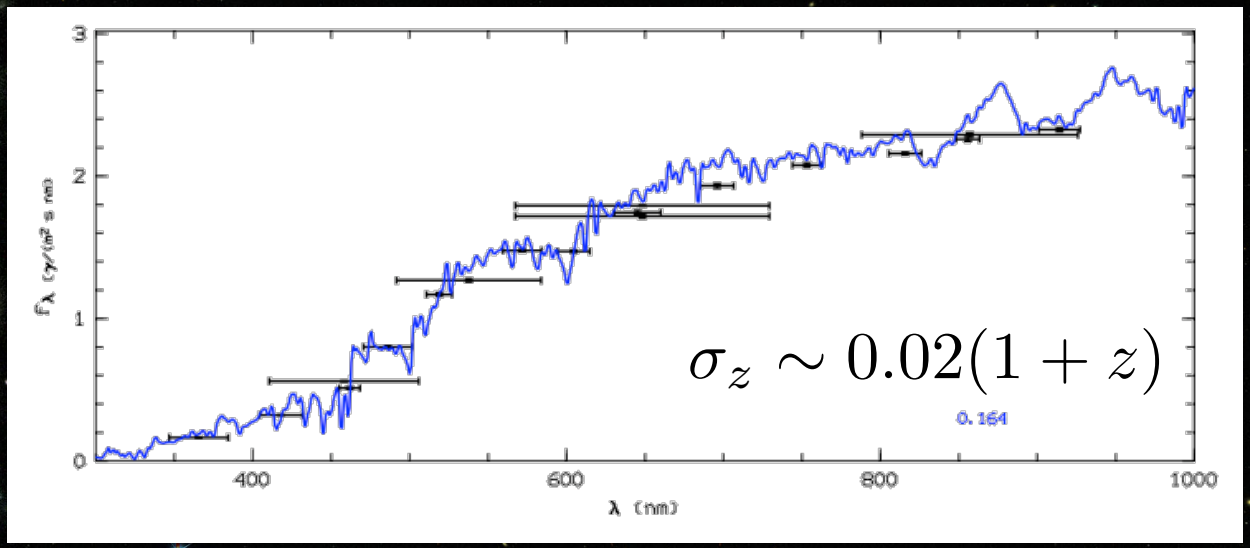
Ground-based images from COMBO-17

LBL 22nd Jan 2008

COMBO-17



Wolf et al 2004

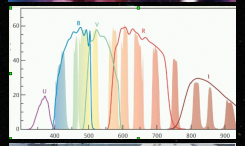


- 5 broad band + 12 narrow band filters
- Photometric redshifts to R<24, accuracy ~0.02
- Clean selection of supercluster galaxies (3%/15% contamination)
- Spectral Energy Distributions; age, dust, metalicity
- Star formation history
- Stellar mass estimate

STAGES: Space Telescope A901/902 Galaxy Evolution Survey

Hubble Space Telescope
(M.E Gray)

80 orbit mosaic; ACS, NICMOS, WFPC
morphologies, weak gravitational lensing



COMBO-17 survey
(C. Wolf)

17-band optical imaging:
photo-zs + SEDs for 15000 objects

Omega2000 @ Calar Alto
(K. Meisenheimer)

near-infrared extension (Y, J1, J2, H):
M*, photo-zs

2dF spectrograph
(M. E. Gray)

spectroscopy of ~300 cluster galaxies:
dynamics, star-formation histories

XMM-Newton
(R. Gilmour)

90 ks X-ray imaging/spectroscopy:
ICM, AGN

Spitzer
(E. F. Bell)

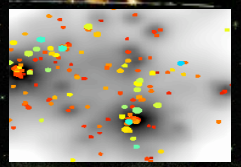
infrared imaging (8 and 24 μm):
obscured star formation, AGN

GALEX
(GALEX team)

NUV + FUV imaging:
unobscured star formation

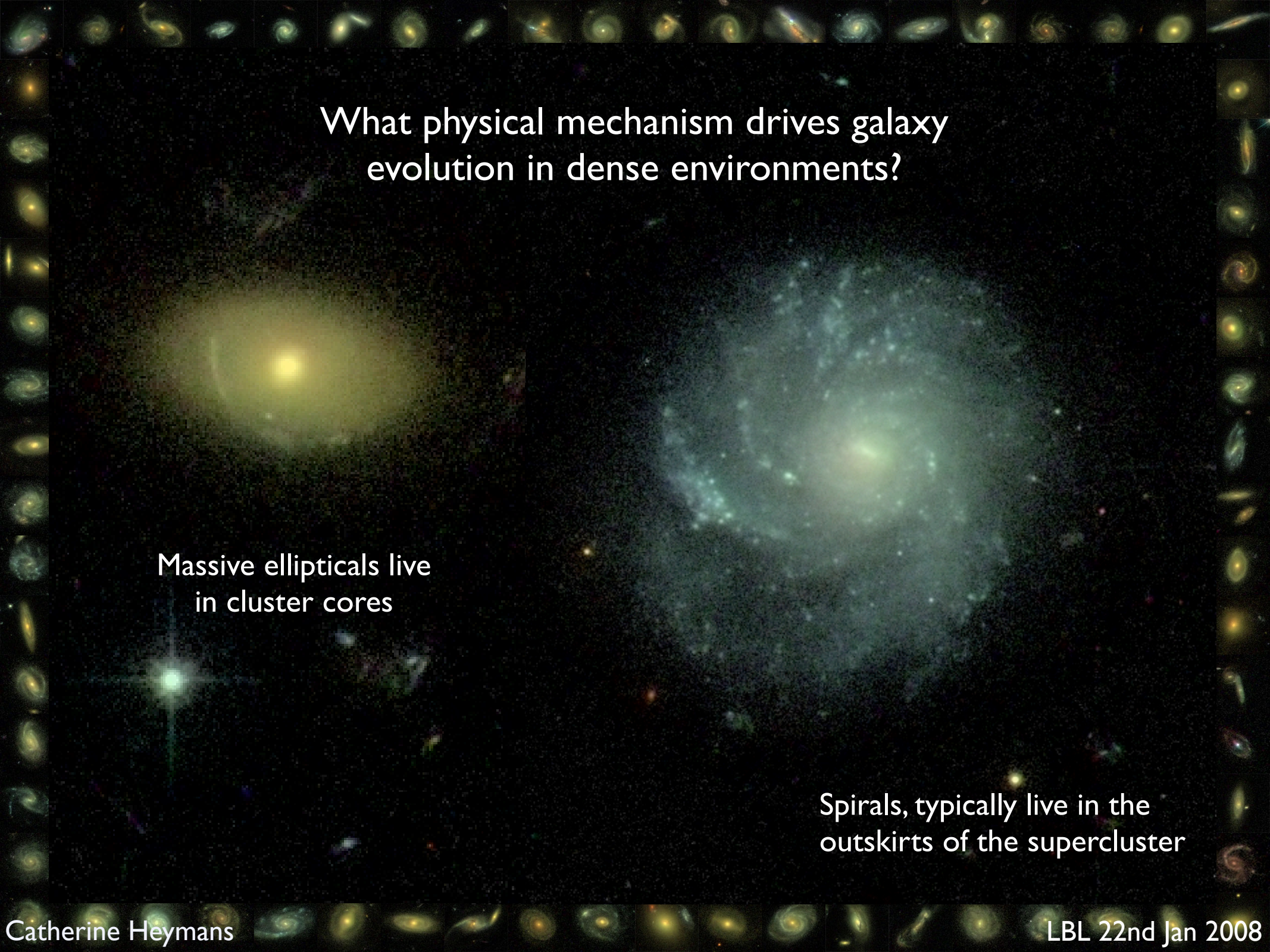
GMRT
(D. Green)

radio imaging (610 and 1400MHz)
obscured SF, AGN

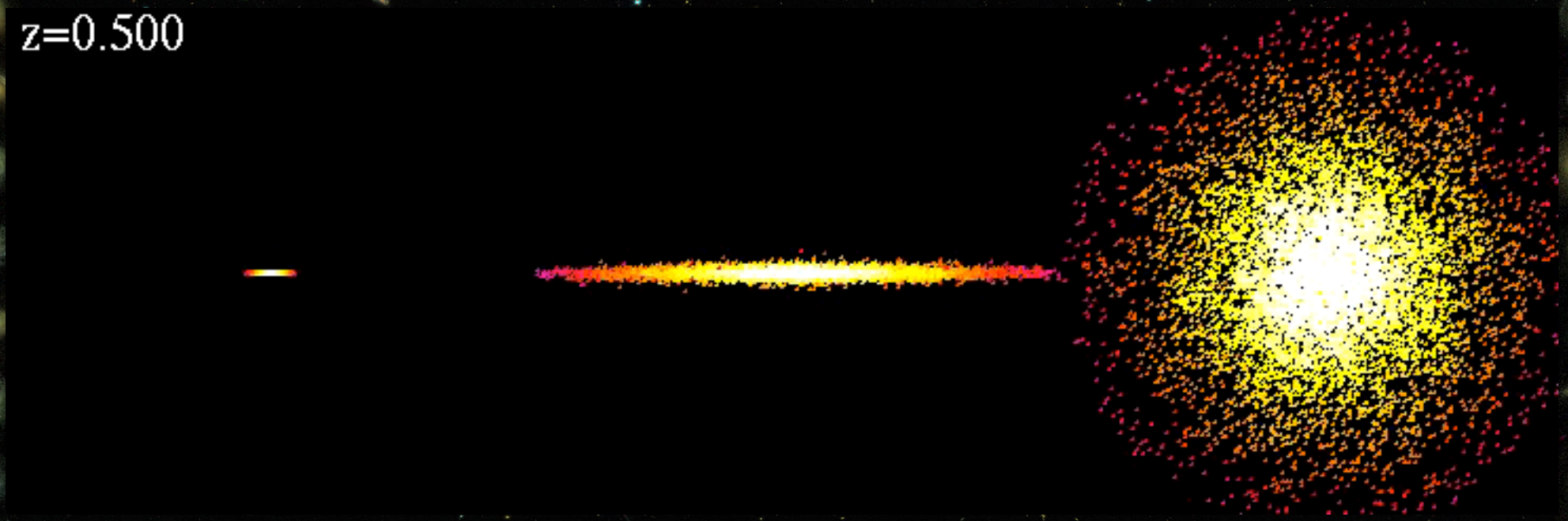


constrained simulations
(E. van Kampen)

N-body + hydro + semi-analytic models
dark matter, gas, galaxies


What physical mechanism drives galaxy evolution in dense environments?
Massive ellipticals live in cluster cores
Spirals, typically live in the outskirts of the supercluster

1: Galaxy-cluster gravitational interations:



LSB galaxy

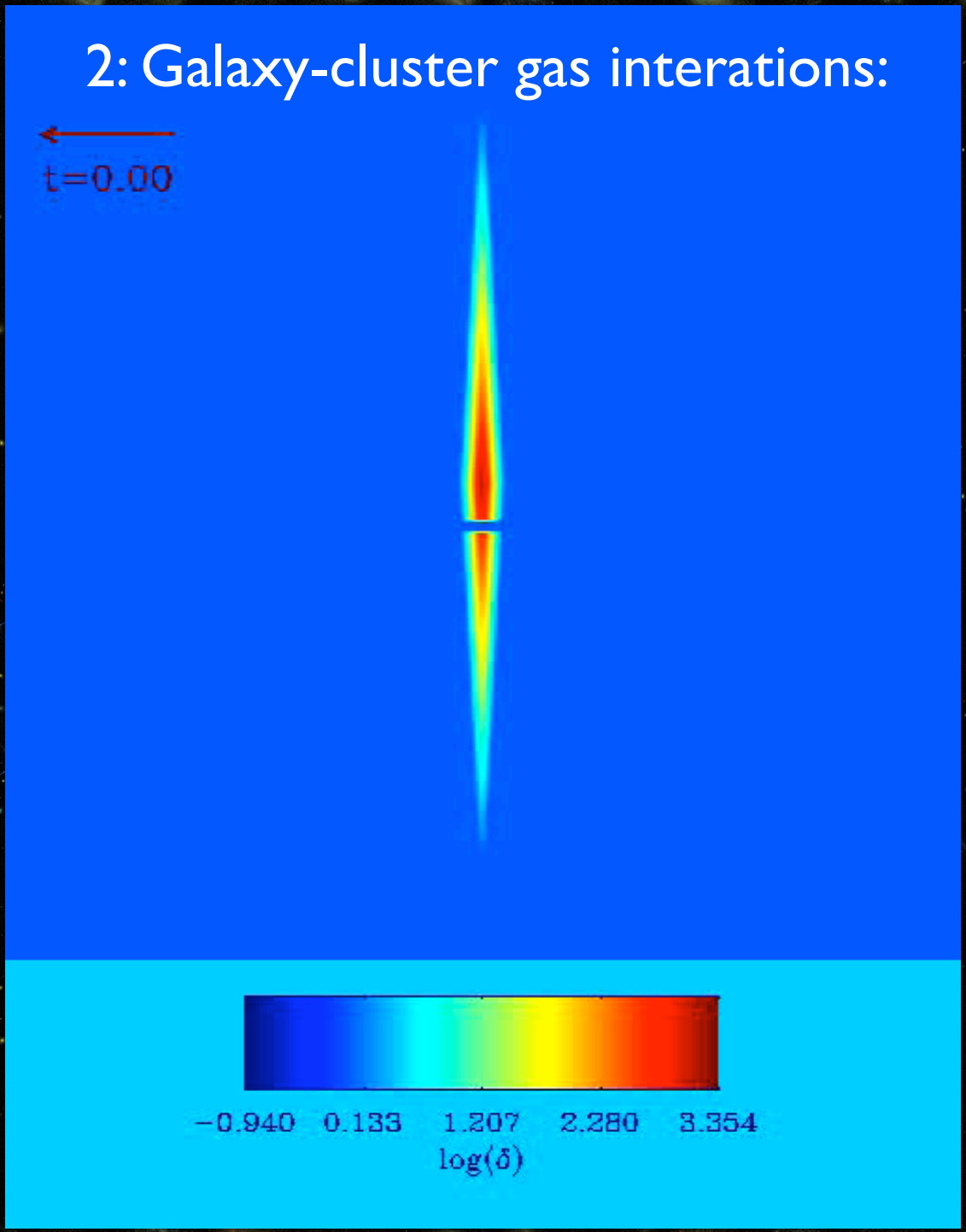
Zoom in: Side on view

Zoom in: Face on view

Galaxy Harassment movie: The evolution of a low surface brightness galaxy as it falls into a cluster (Moore et al 1998)

2: Galaxy-cluster gas interations:

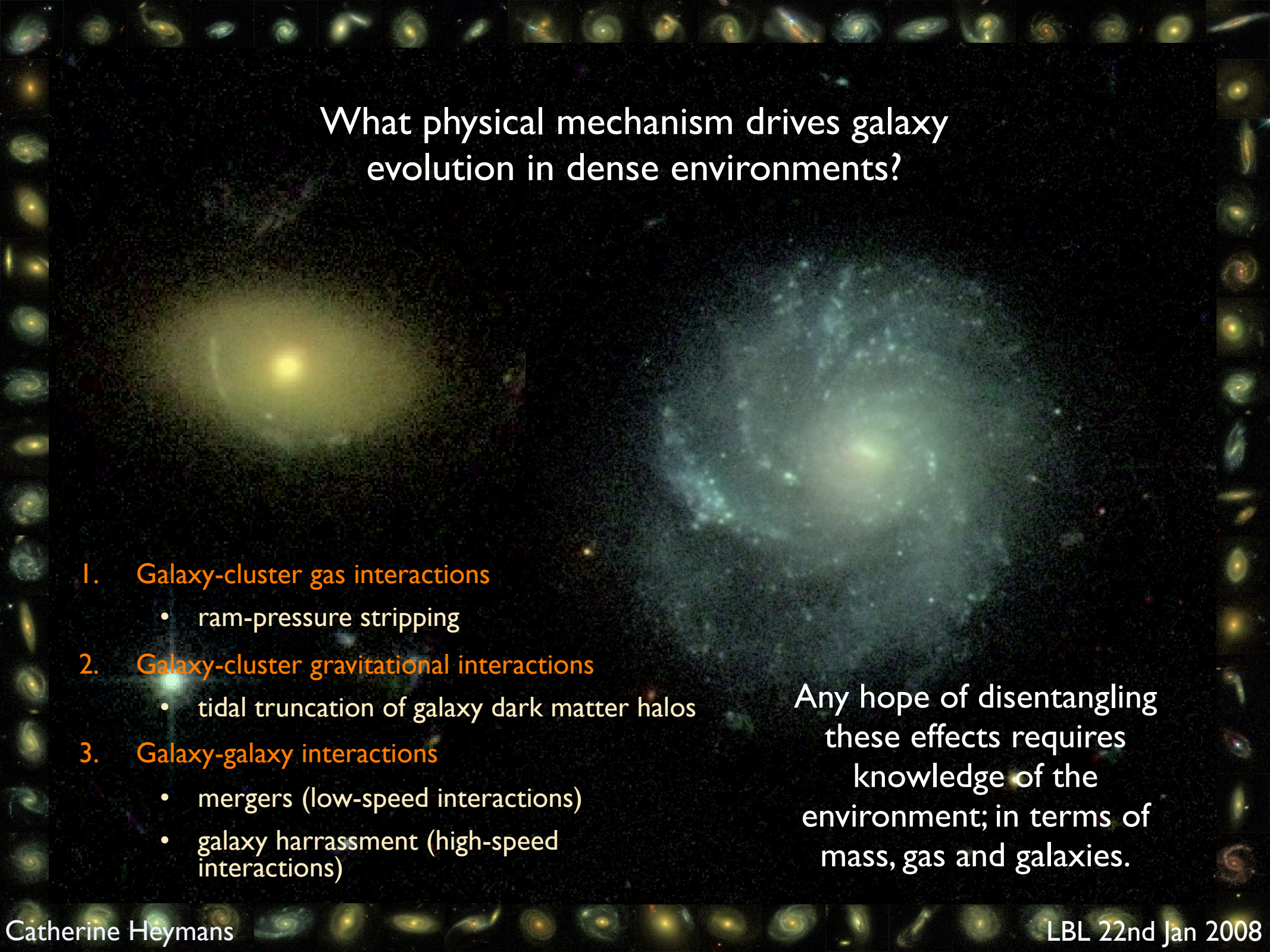
Ram pressure stripping: The turbulent history of a spiral galaxy as it falls through the hot ICM of a rich galaxy cluster (Quilis et al).



3: Galaxy-cluster galaxy interations:

Galaxy Merger movie (Dubinski et al)

What physical mechanism drives galaxy evolution in dense environments?



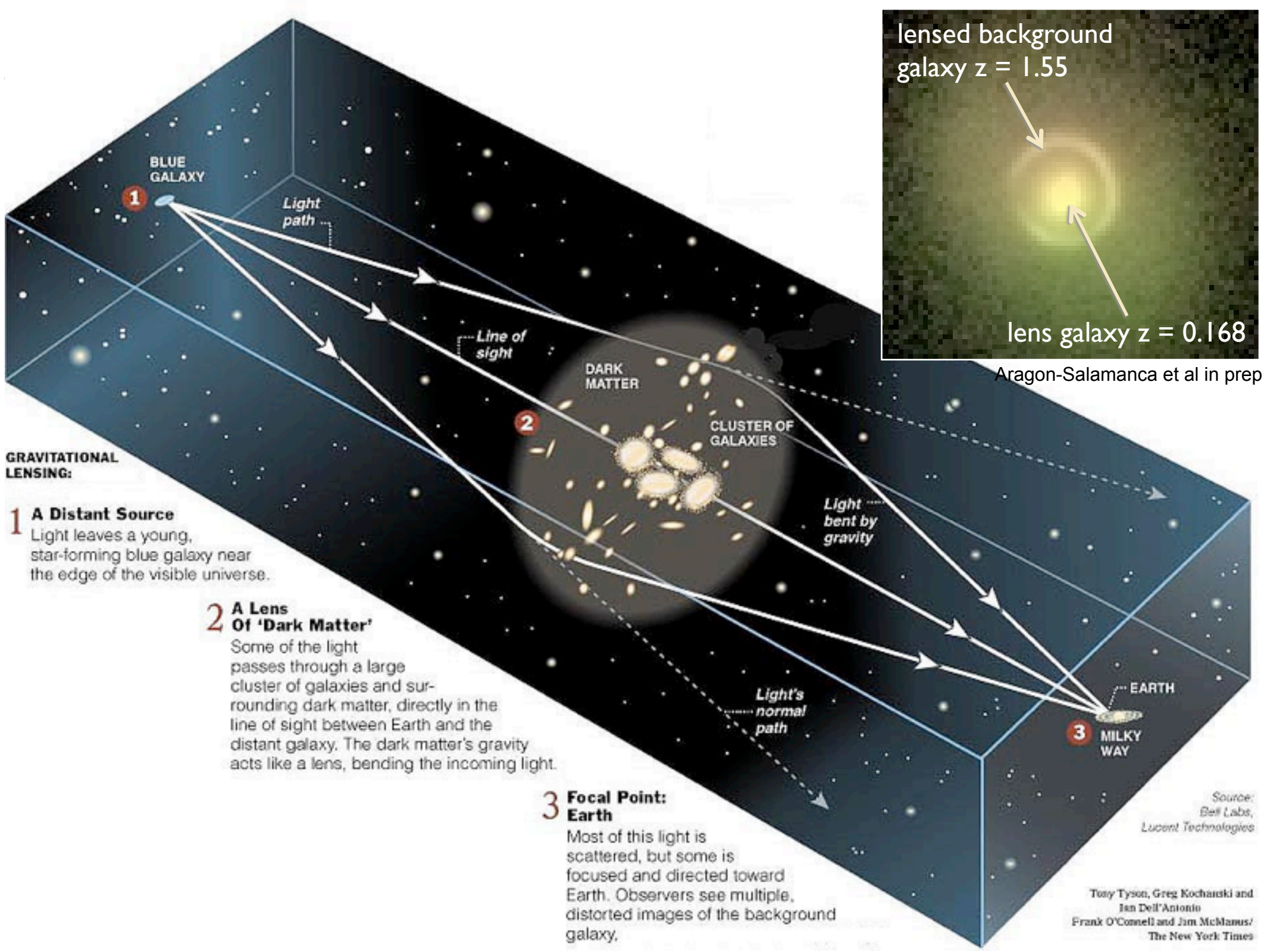
1. Galaxy-cluster gas interactions
   - ram-pressure stripping
2. Galaxy-cluster gravitational interactions
   - tidal truncation of galaxy dark matter halos
3. Galaxy-galaxy interactions
   - mergers (low-speed interactions)
   - galaxy harrassment (high-speed interactions)

Any hope of disentangling these effects requires knowledge of the environment; in terms of mass, gas and galaxies.


Dark Matter is the underlying structure of the Universe,
dictating where and when galaxies form.
The Millennium simulation: Max Planck Institute

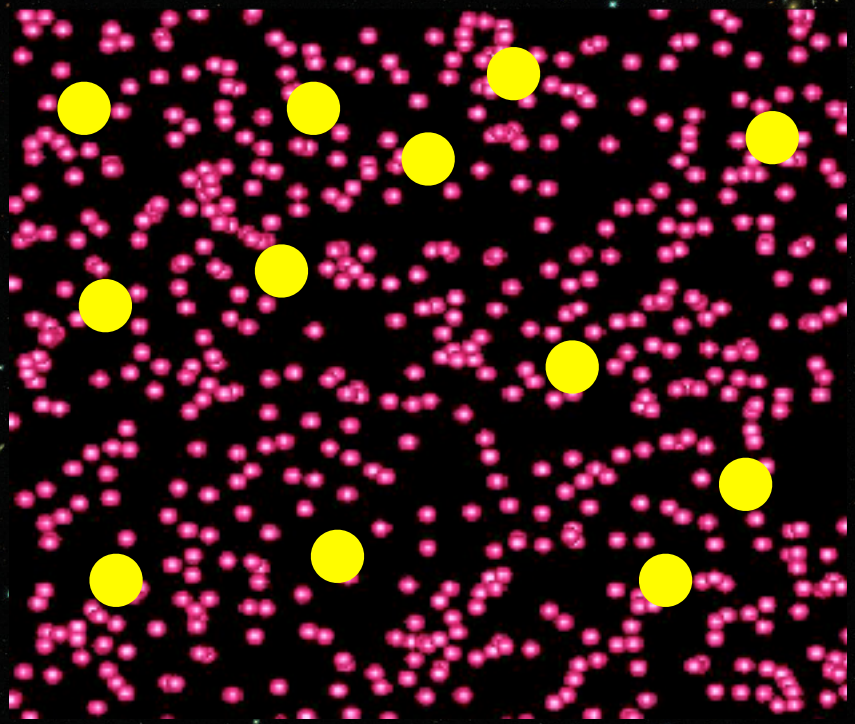
Seeing the invisible

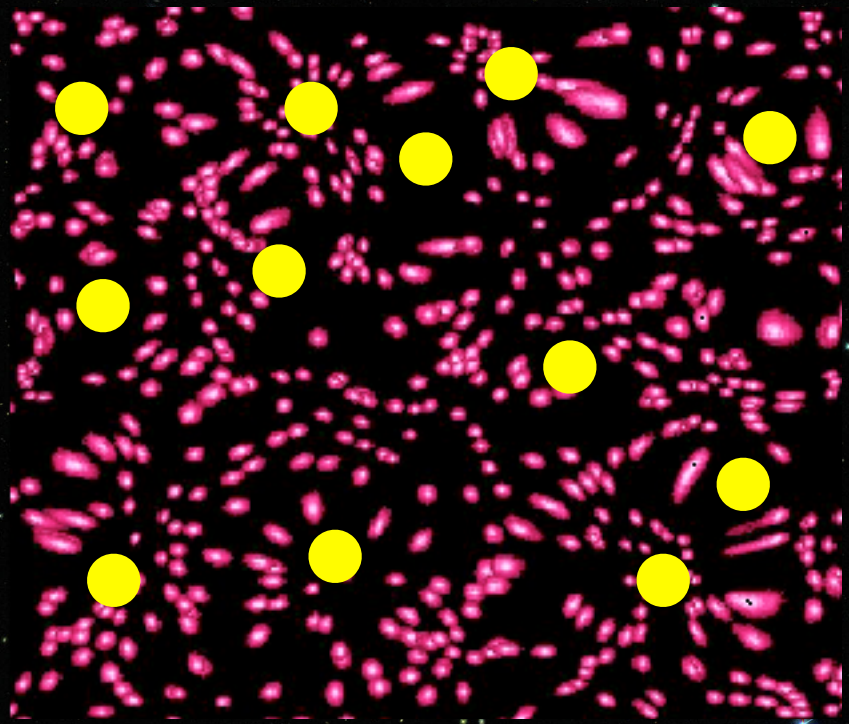
Seeing the invisible



Aragon-Salamanca et al in prep

The dark matter signature on the sky



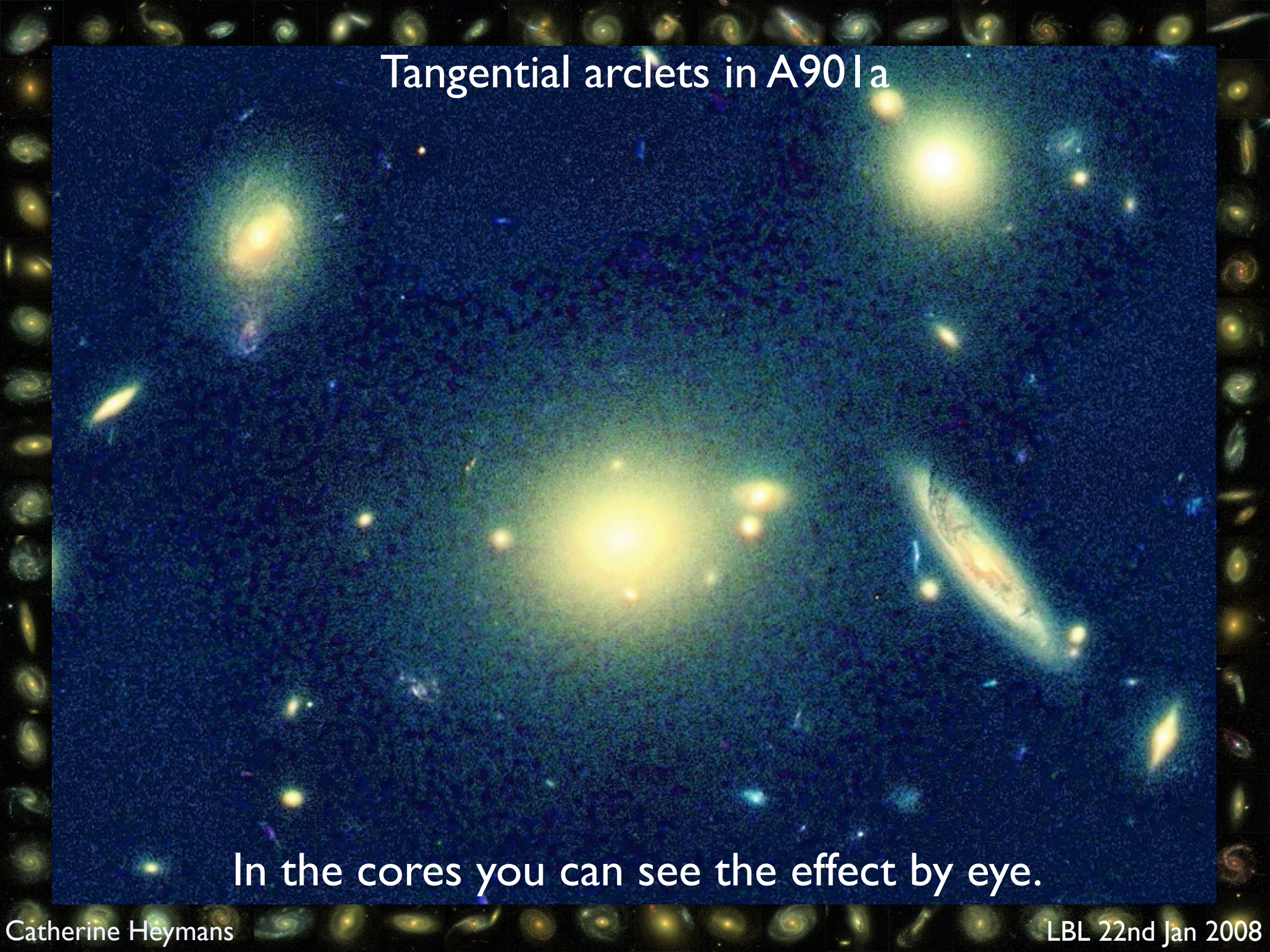


Distant galaxies

Matter

Dark Matter

We can use the 'lensing' signature of dark matter to tell us where is it and how much if it there is.


Tangential arclets in A901a
In the cores you can see the effect by eye.

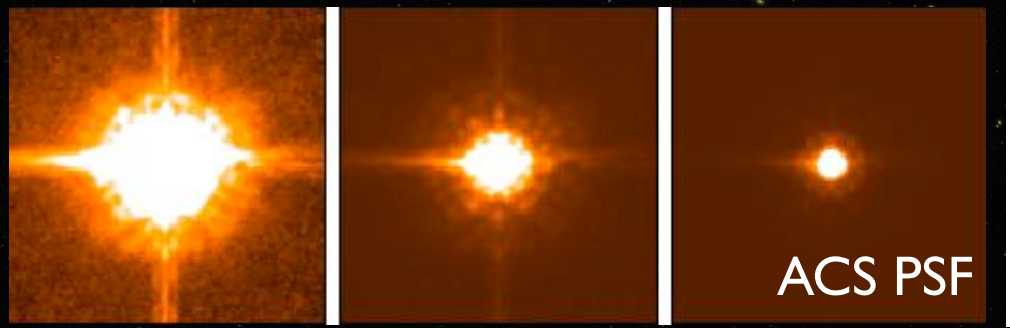
How to make a dark matter map

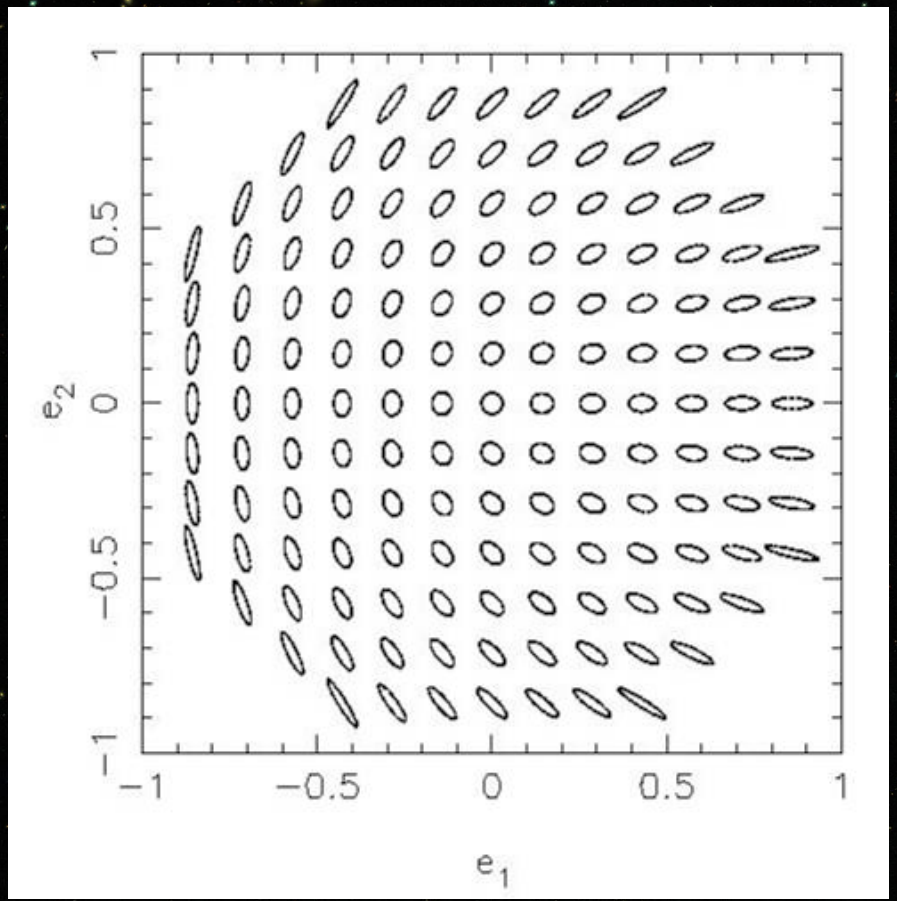
1. Obtain deep high resolution imaging.
2. Measure the ellipticities of distant galaxies.
3. Account for all artifical sources of shear (eg instrumental distortions) that are typically more than an order of magnitude larger than the signal you're trying to detect (see STEP).
4. Directly from GR you can relate the measured shear to the projected mass.

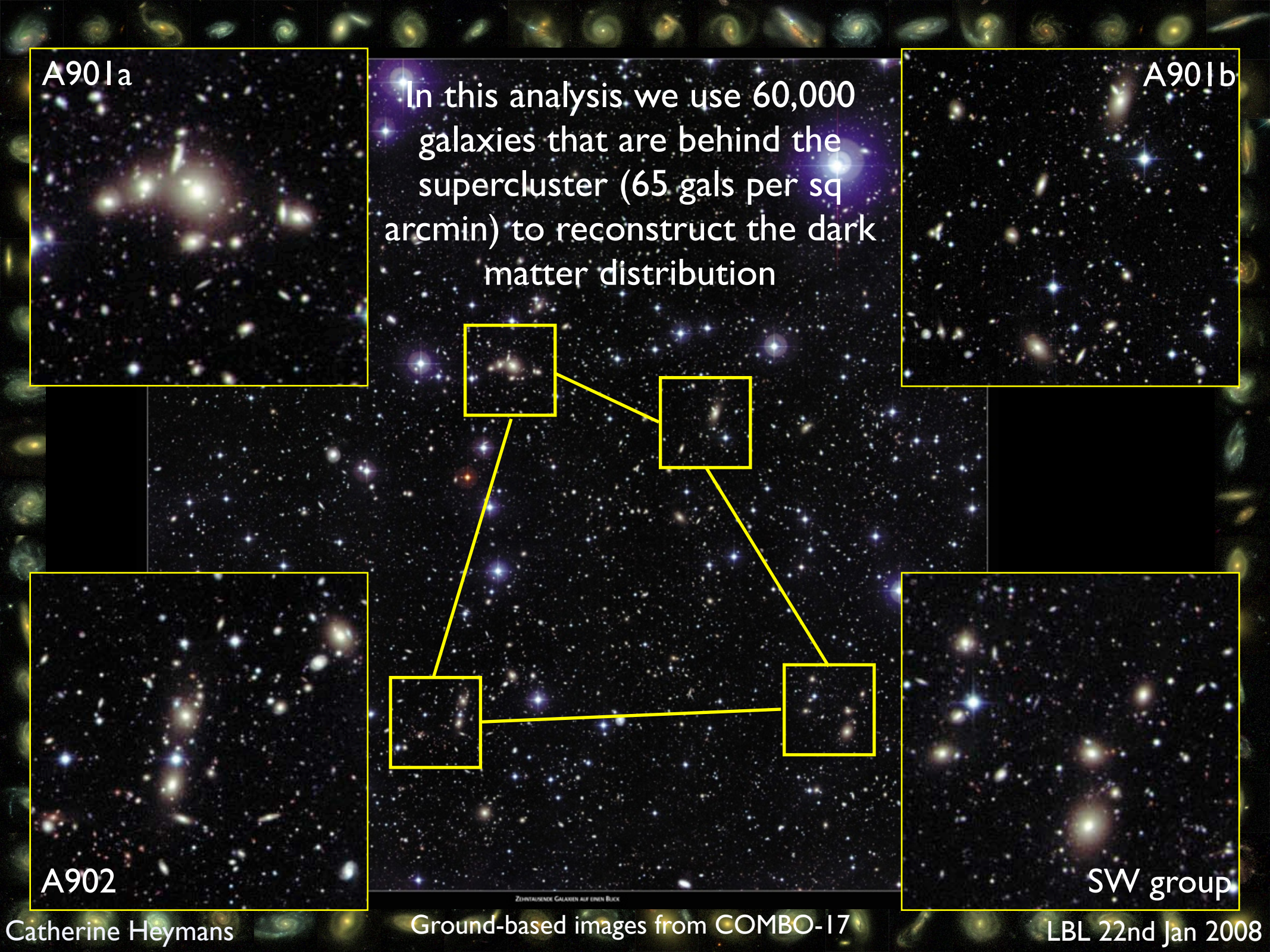
$$e_i = e_i^{source} + \gamma_i$$

$$\langle e_i^{source} \rangle = 0$$

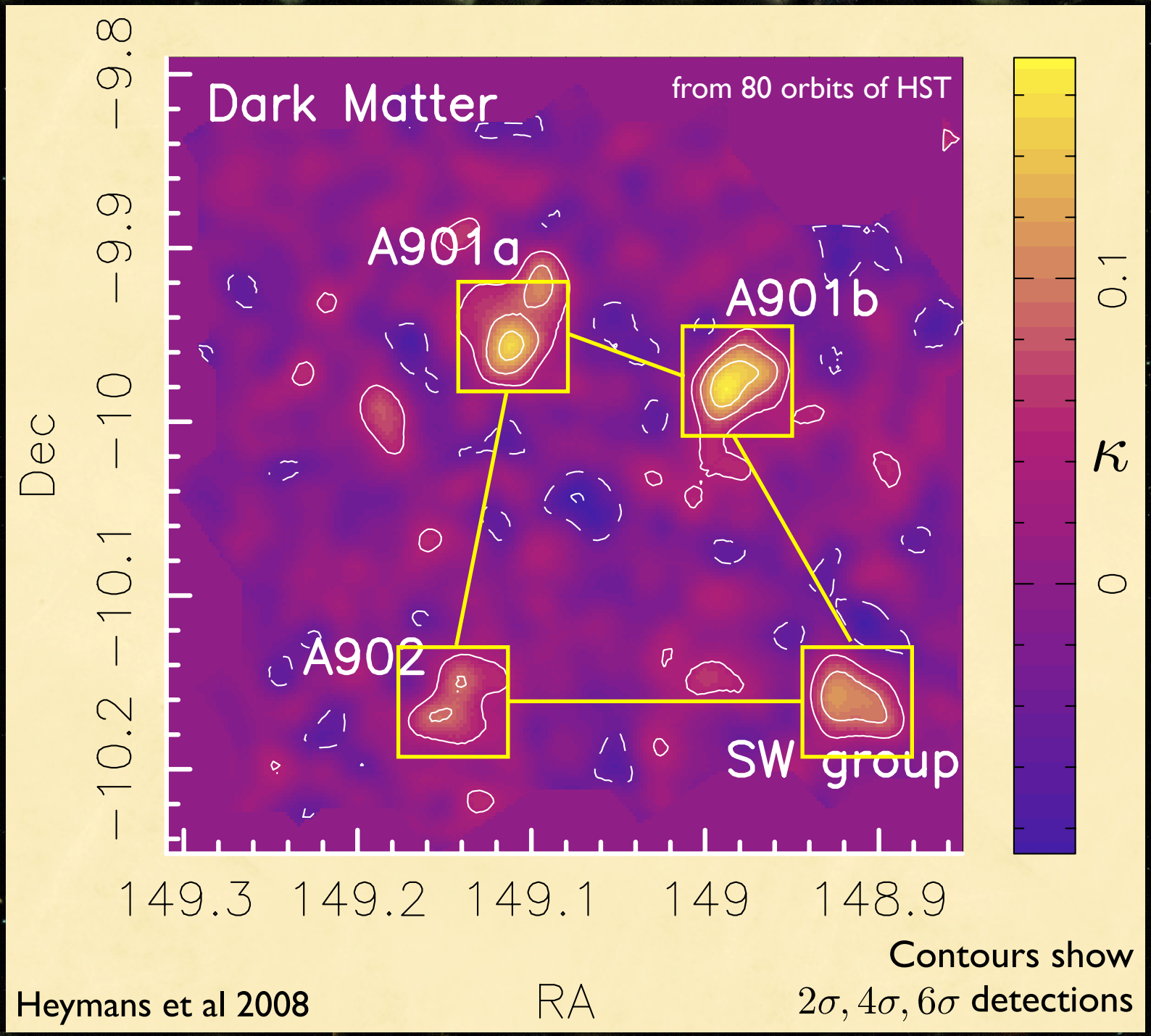
$$\gamma \approx \langle e \rangle$$



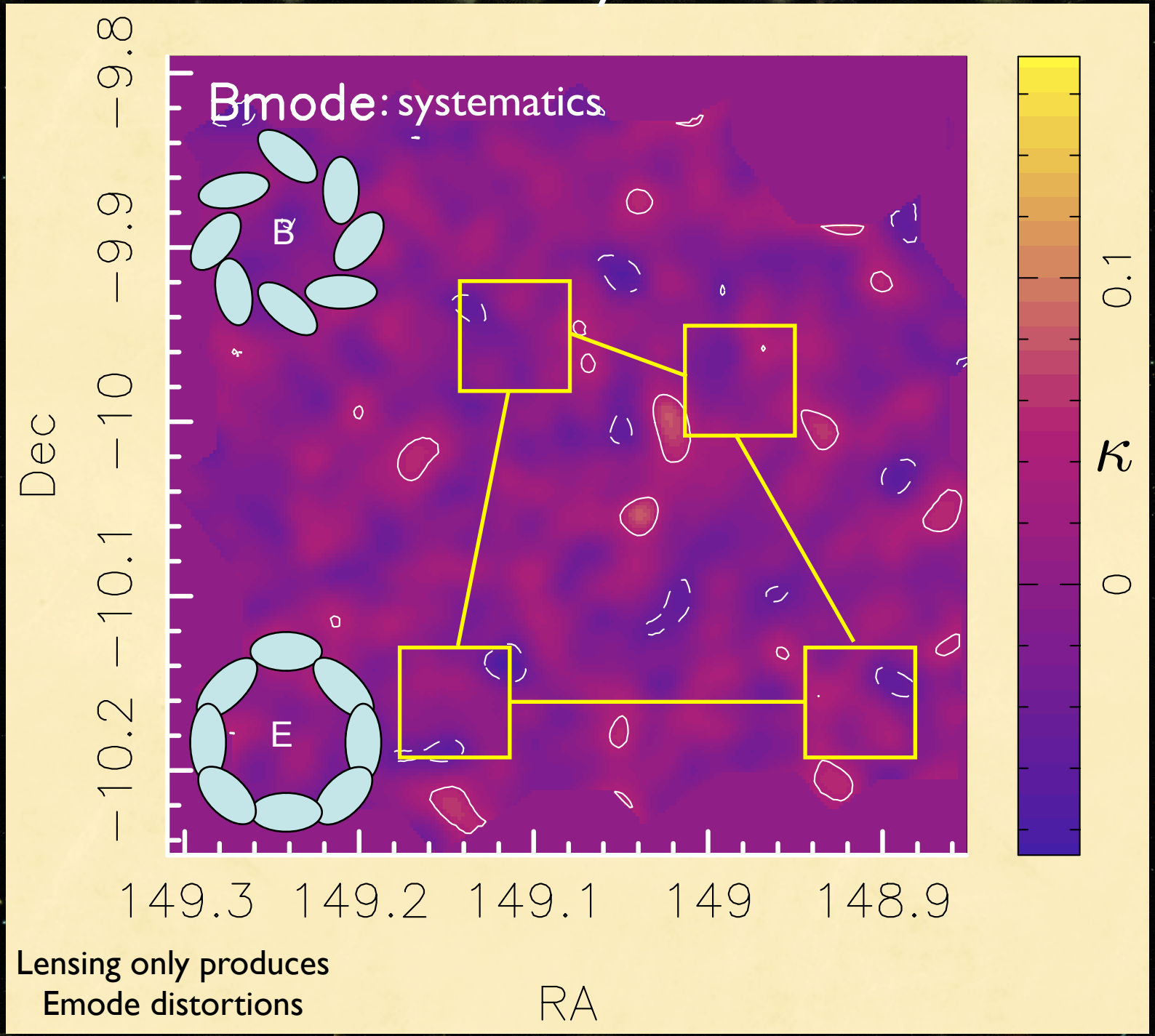



A901a
In this analysis we use 60,000 galaxies that are behind the supercluster (65 gals per sq arcmin) to reconstruct the dark matter distribution
A901b
A902
SW group
Zehntausende Galaxien auf einen Blick
Catherine Heymans
Ground-based images from COMBO-17
LBL 22nd Jan 2008

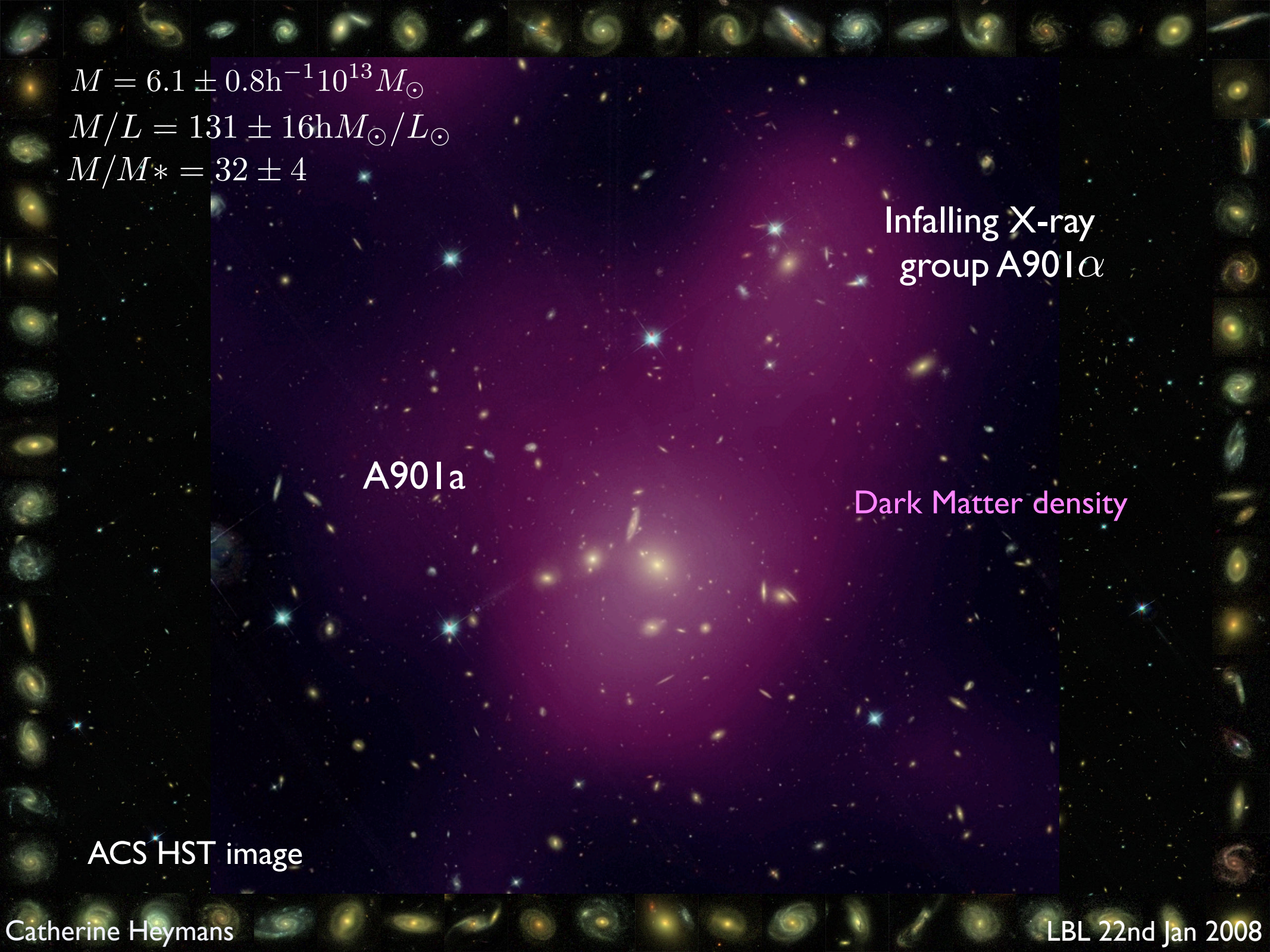
130kpc resolution at supercluster redshift z=0.165



What about systematics?



Lensing only produces
Emode distortions


$M = 6.1 \pm 0.8 \mathrm{h}^{-1} 10^{13} M_\odot$
$M/L = 131 \pm 16 \mathrm{h} M_\odot / L_\odot$
$M/M* = 32 \pm 4$
Infalling X-ray group A901α
A901a
Dark Matter density
ACS HST image

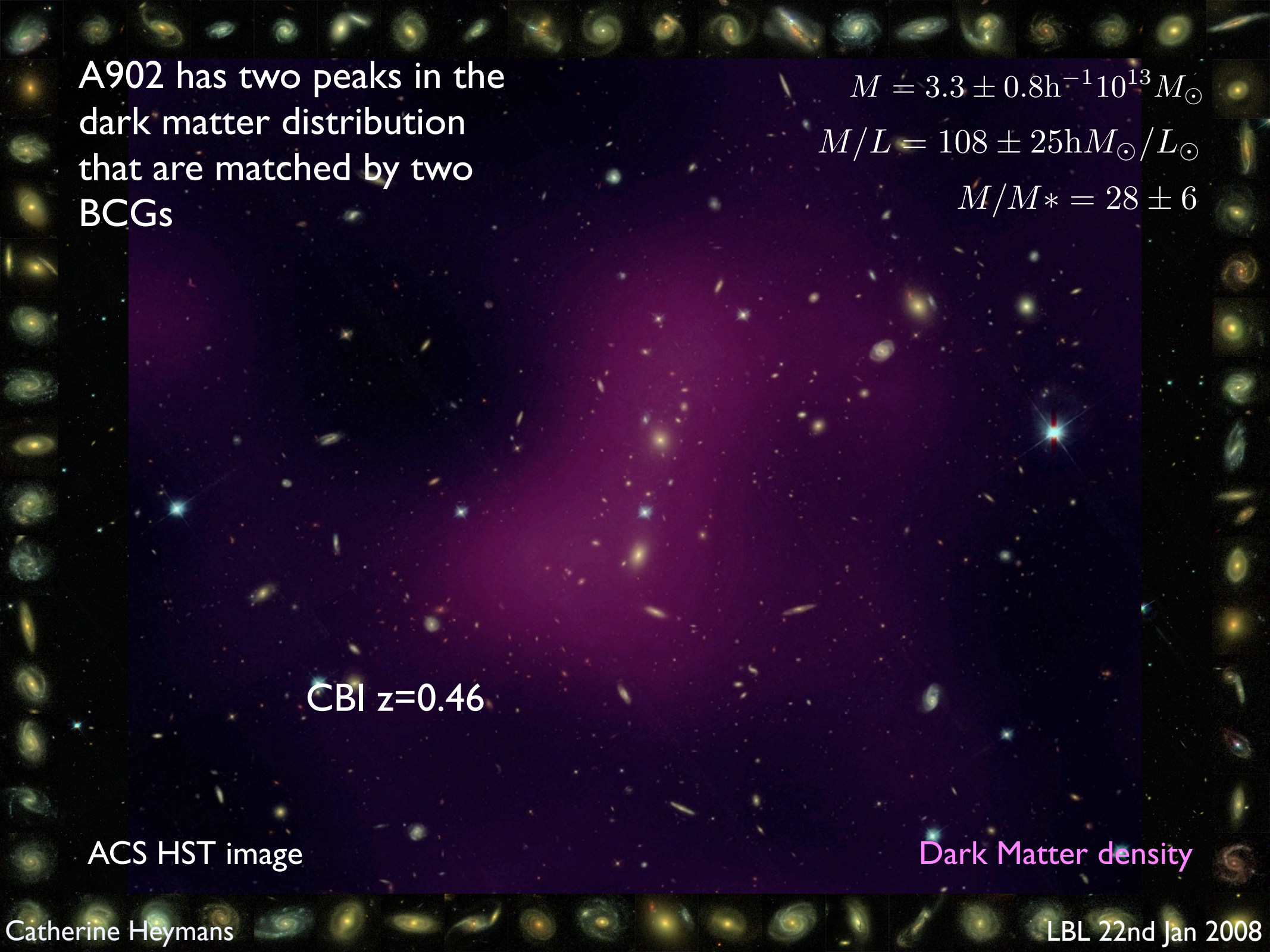
A901b: the most massive and X-ray rich of the four clusters

$$M = 6.5 \pm 1.3 \mathrm{h}^{-1} 10^{13} M_{\odot}$$
$$M/L = 165 \pm 33 \mathrm{h} M_{\odot}/L_{\odot}$$
$$M/M* = 42 \pm 8$$

Dark Matter map resolves substructure

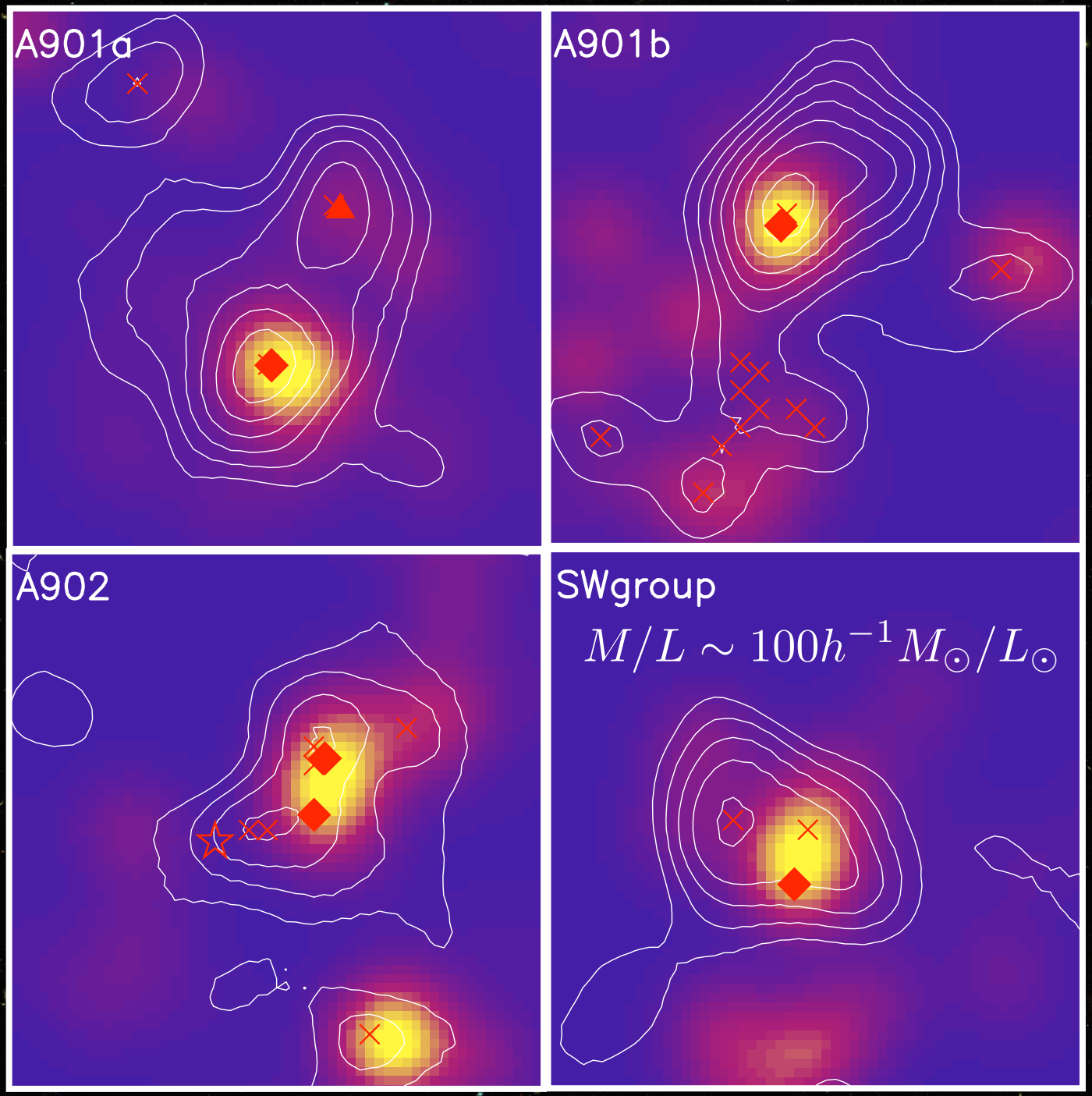
ACS HST image

Dark Matter density

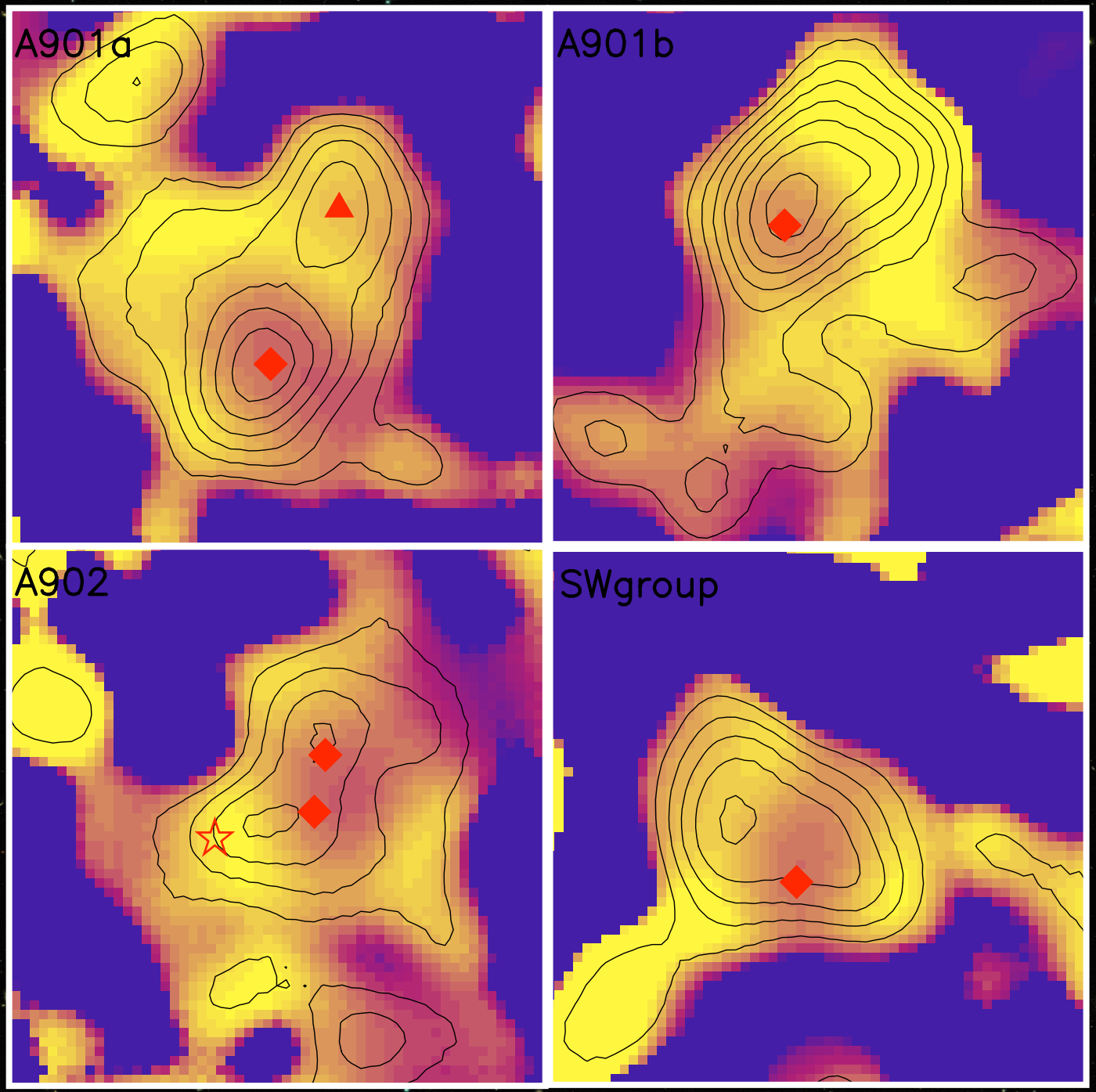

A902 has two peaks in the dark matter distribution that are matched by two BCGs
$M = 3.3 \pm 0.8 \mathrm{h}^{-1} 10^{13} M_\odot$
$M/L = 108 \pm 25 \mathrm{h} M_\odot / L_\odot$
$M/M* = 28 \pm 6$
CBI z=0.46
ACS HST image
Dark Matter density


SW group
$M = 3.8 \pm 0.5 \mathrm{h}^{-1} 10^{13} M_\odot$
$M/L = 176 \pm 24 \mathrm{h} M_\odot / L_\odot$
$M/M* = 41 \pm 6$
ACS HST image
Dark Matter density

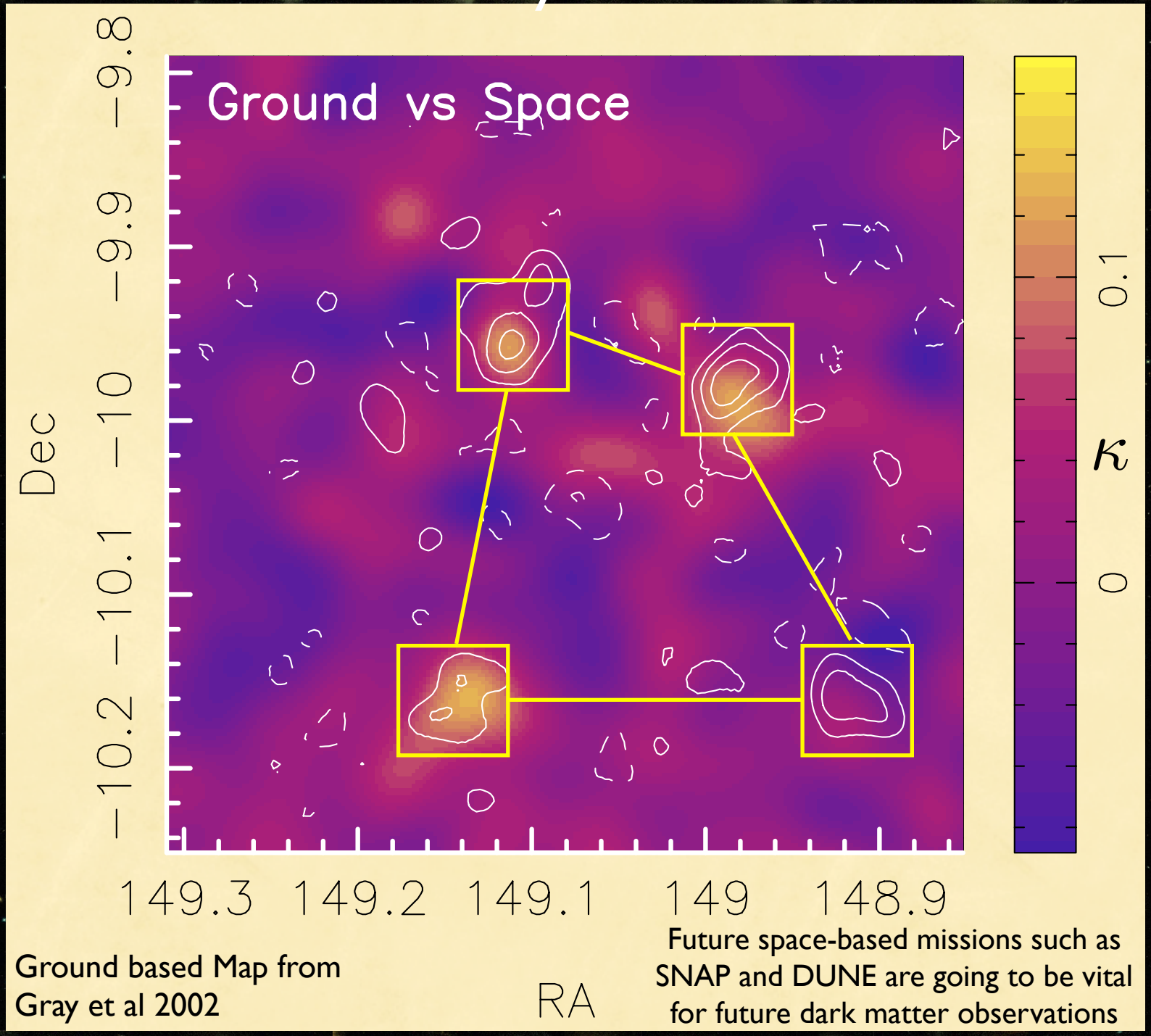
Mass and Light



Mass to stellar mass ratio



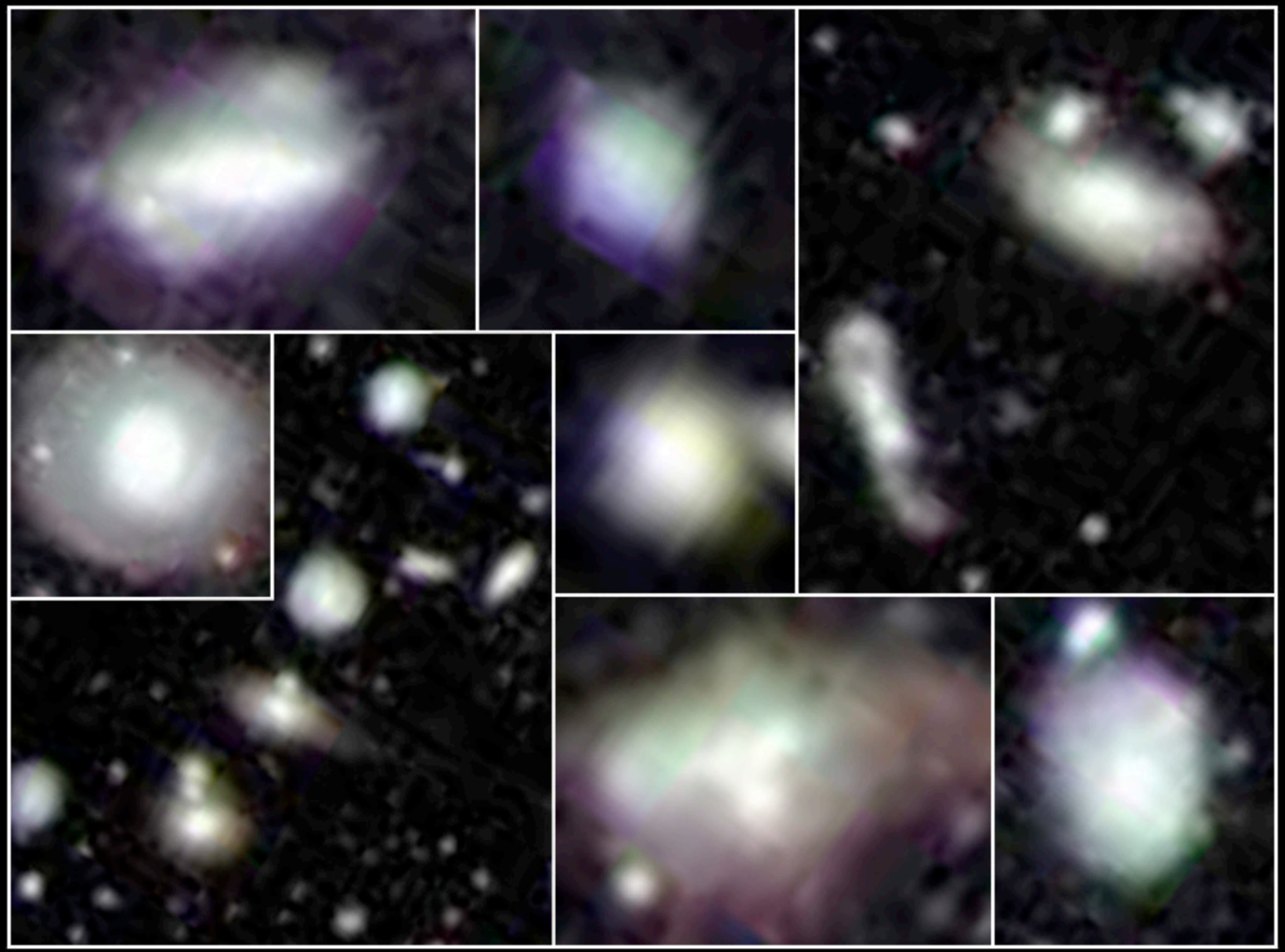
Why HST?



Ground based Map from Gray et al 2002

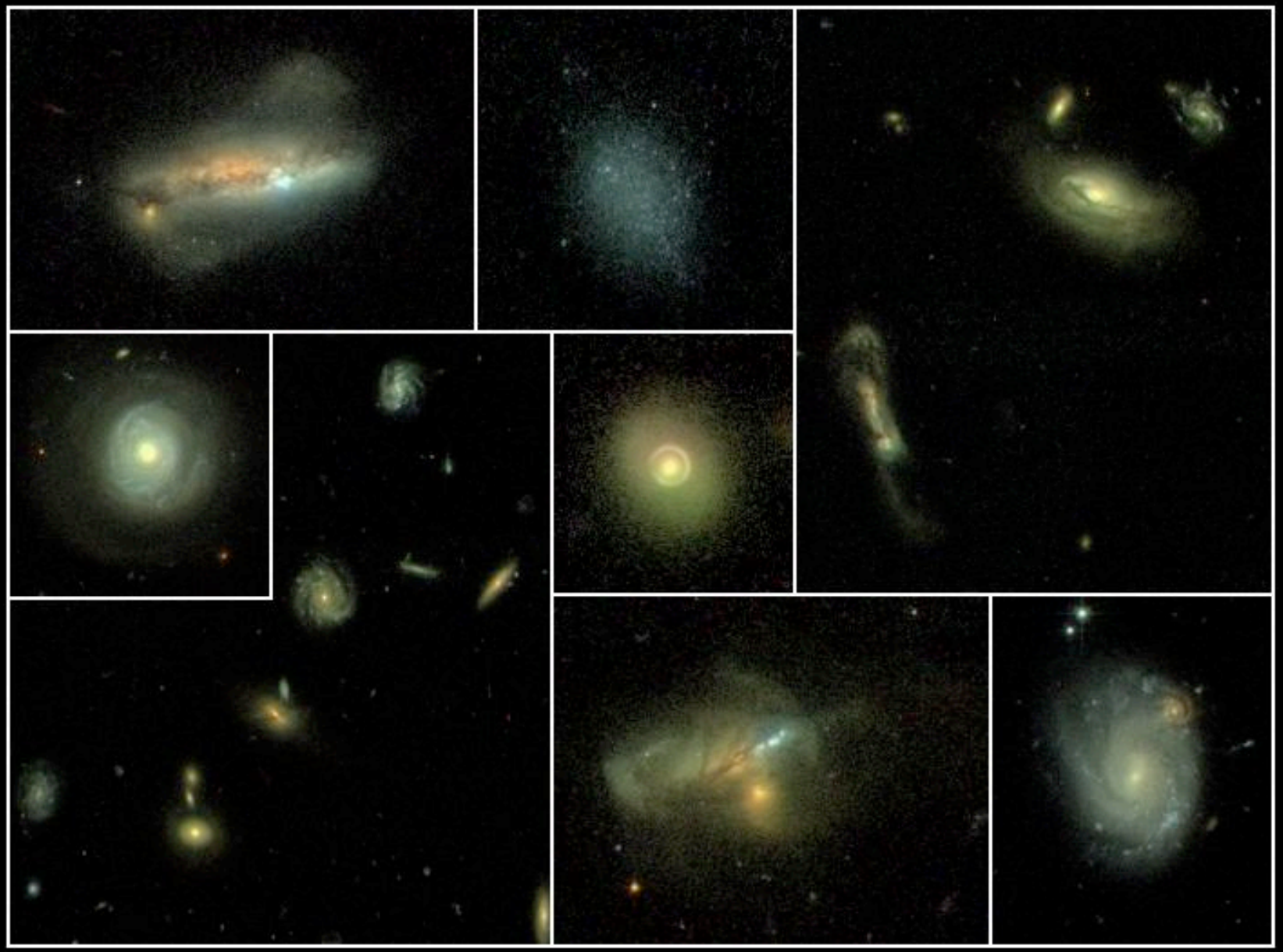
Future space-based missions such as SNAP and DUNE are going to be vital for future dark matter observations

Why Hubble? ground-based



Why Hubble?

STAGES



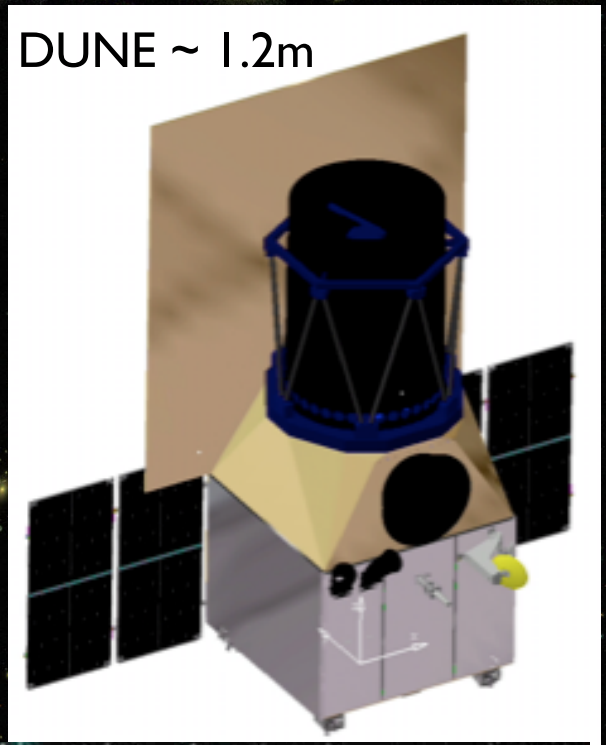
answer: image quality and resolution allows us to detect the weak dark matter signature

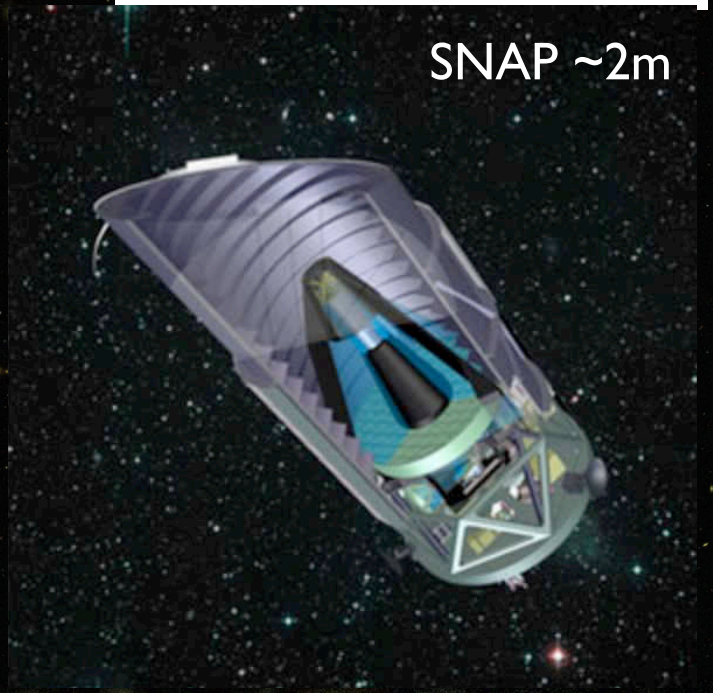
Future telescopes in space: a quick note about depth

- It's not just about image quality.
- For high resolution dark matter maps, you need depth

$$\gamma \approx \langle e \rangle$$

- A smaller class telescope such as DUNE will need to observe much longer than SNAP to obtain deep enough data for simlarly high resolution observations





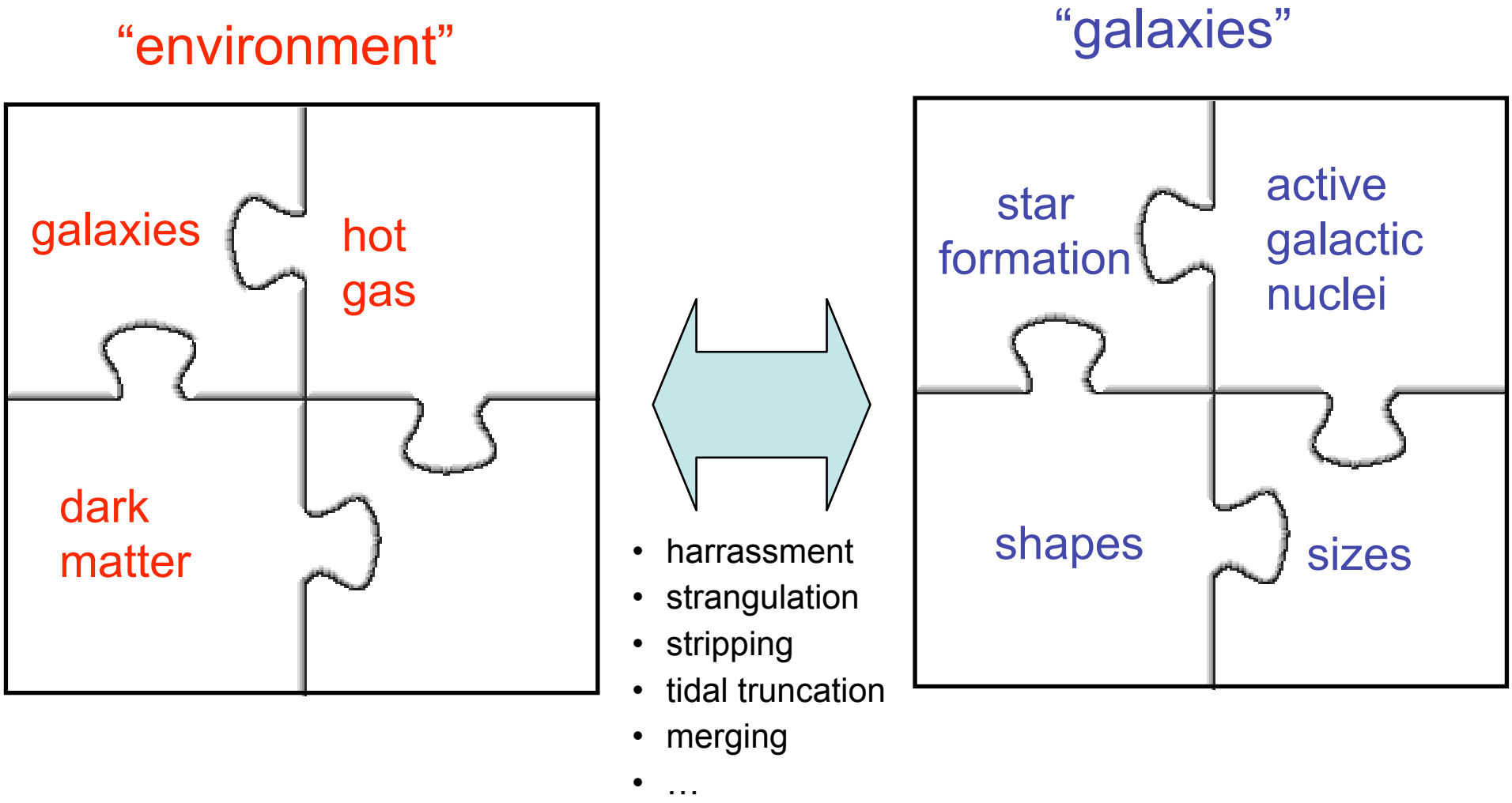
Catherine Heymans

LBL 22nd Jan 2008

STAGES:
Space Telescope A901/902 Galaxy Evolution Survey

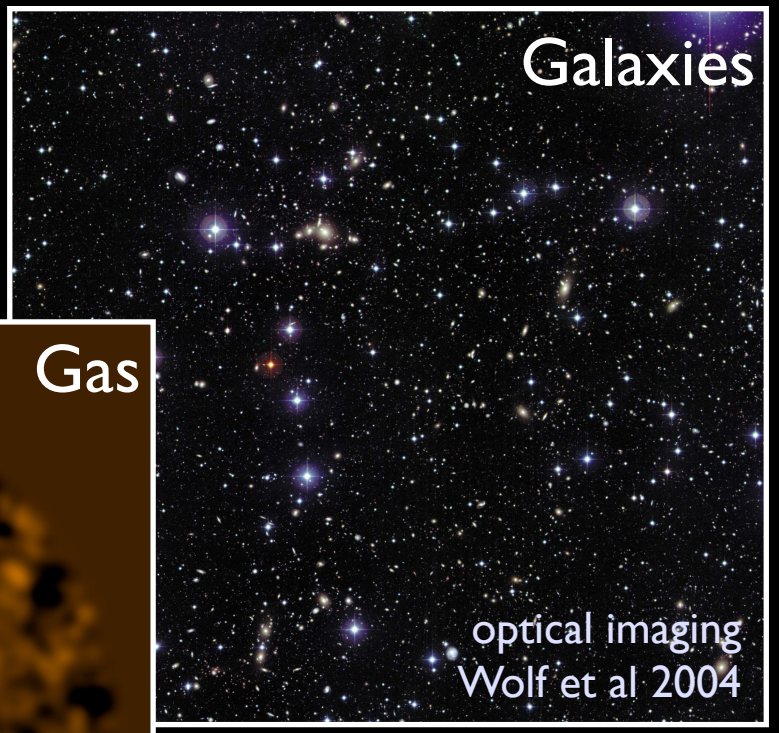
- The lensing map is one key piece of a bigger puzzle
- The larger picture looks at the link between galaxies and environment: nature vs nurture?
- Looking at the A901/902 with multi-wavelength eyes we have assembled an ideal laboratory for studying galaxy evolution
- We are finding that it is the outskirts of the cluster where galaxy transformations are occurring

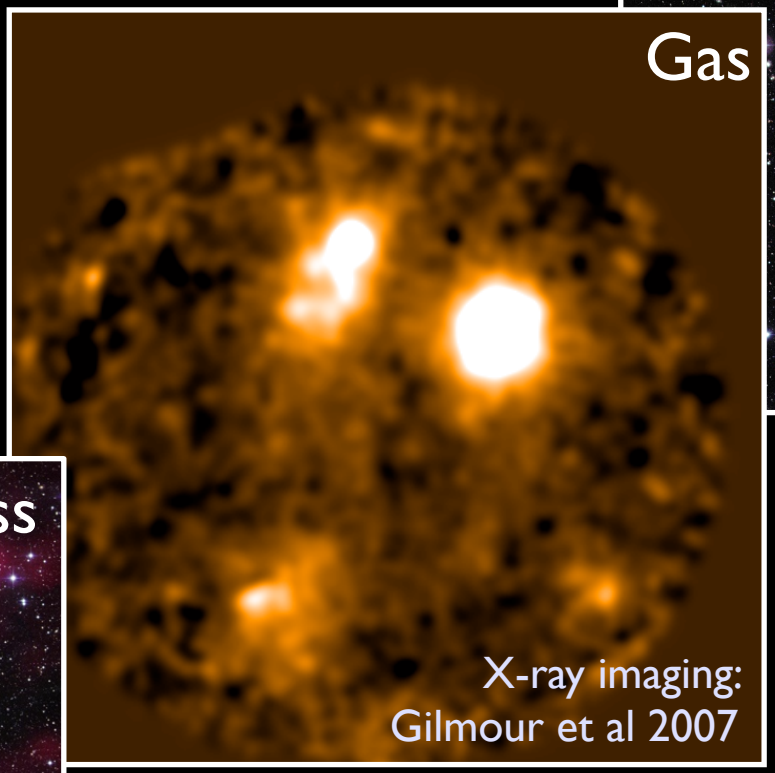
STAGES: a laboratory for studying galaxy evolution and environment

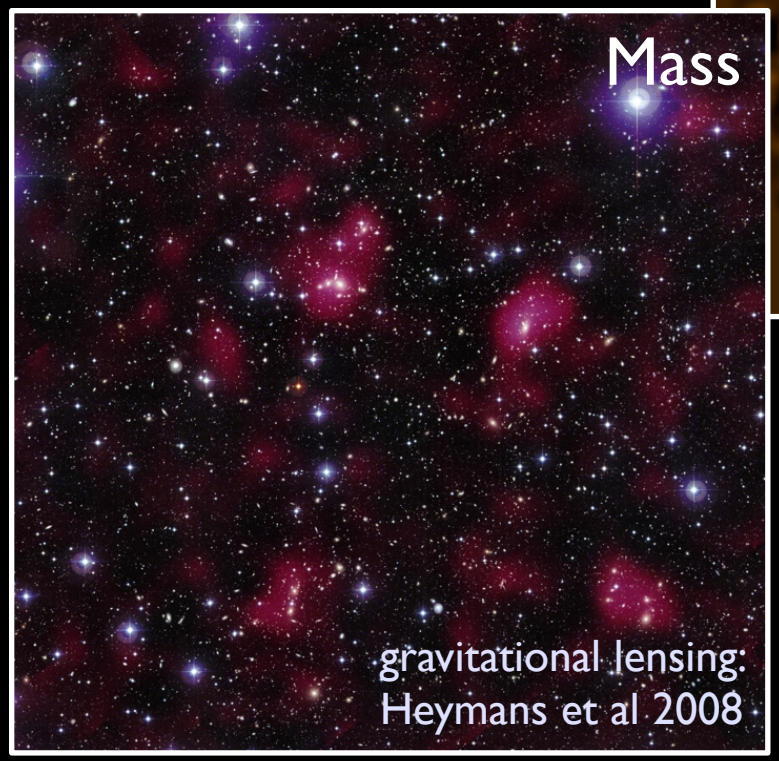


We need multiwavelength observations in order to get a full census of the supercluster.

Anatomy of a supercluster: a complex environment

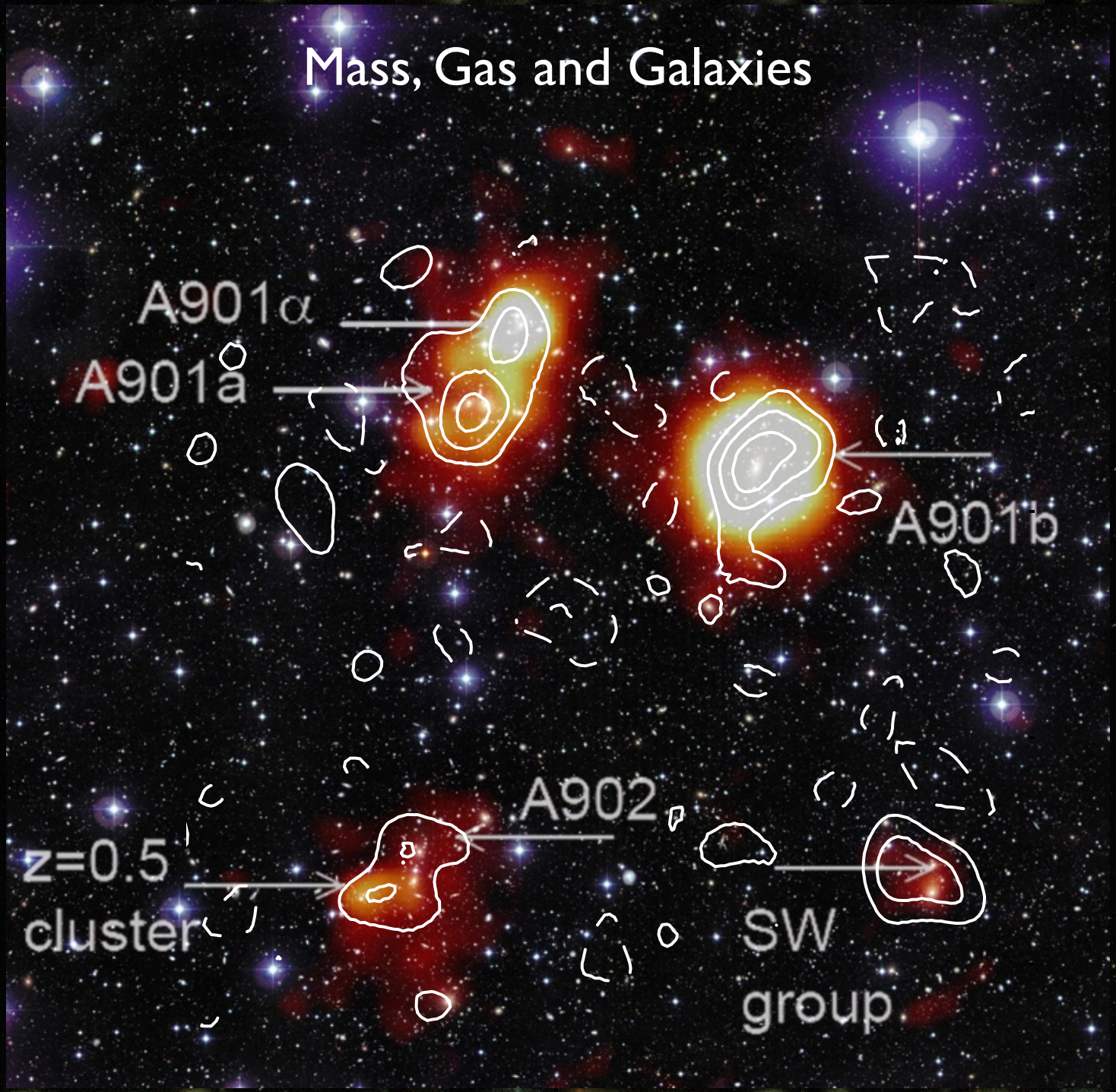






Step 1: map out the environment

Mass, Gas and Galaxies



Step 2: understand the galaxies

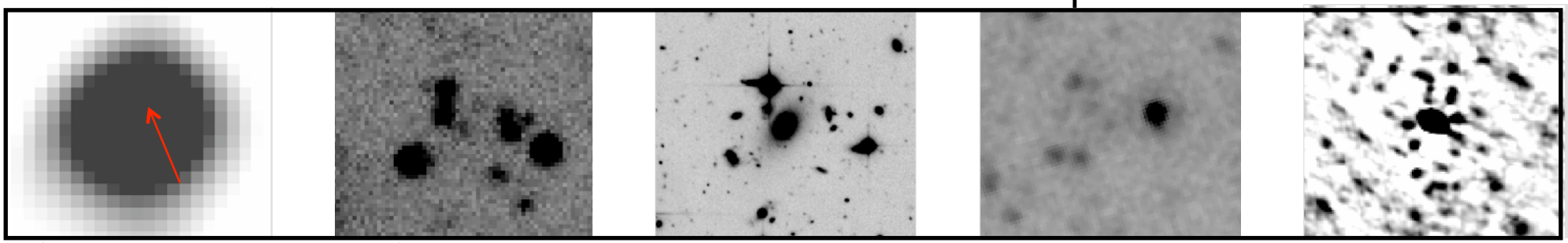

XMM


GALEX

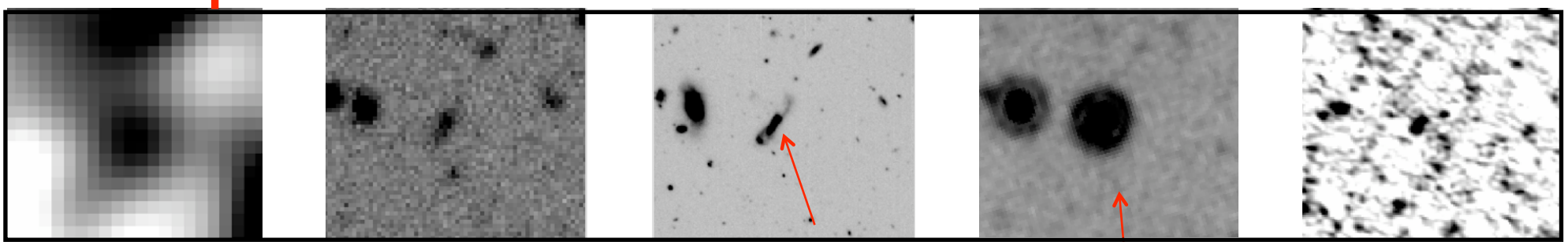

HST

Spitzer

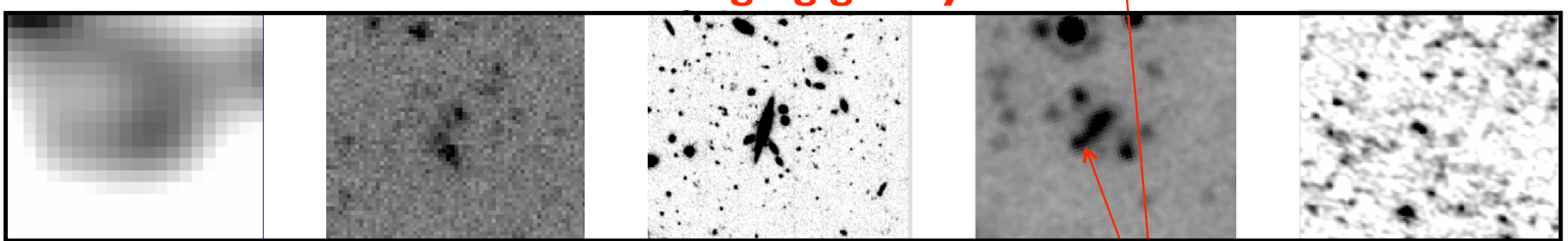

GMRT



hidden supermassive black hole



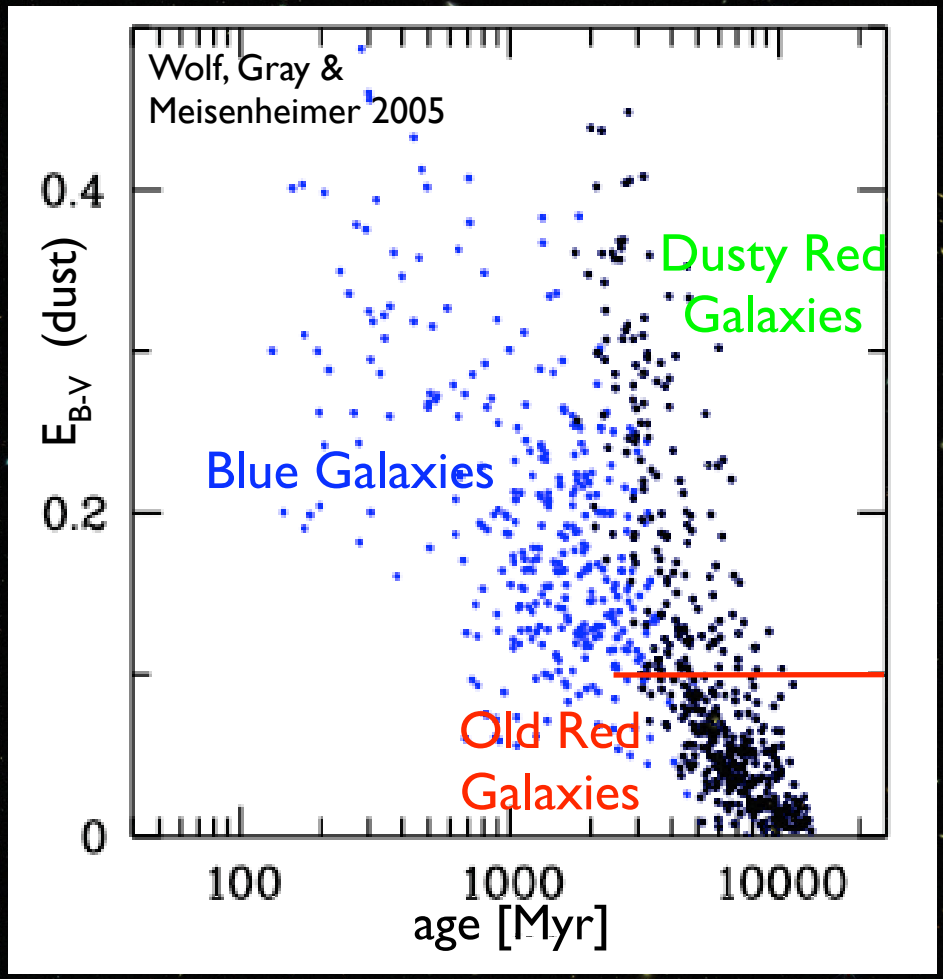
merging galaxy



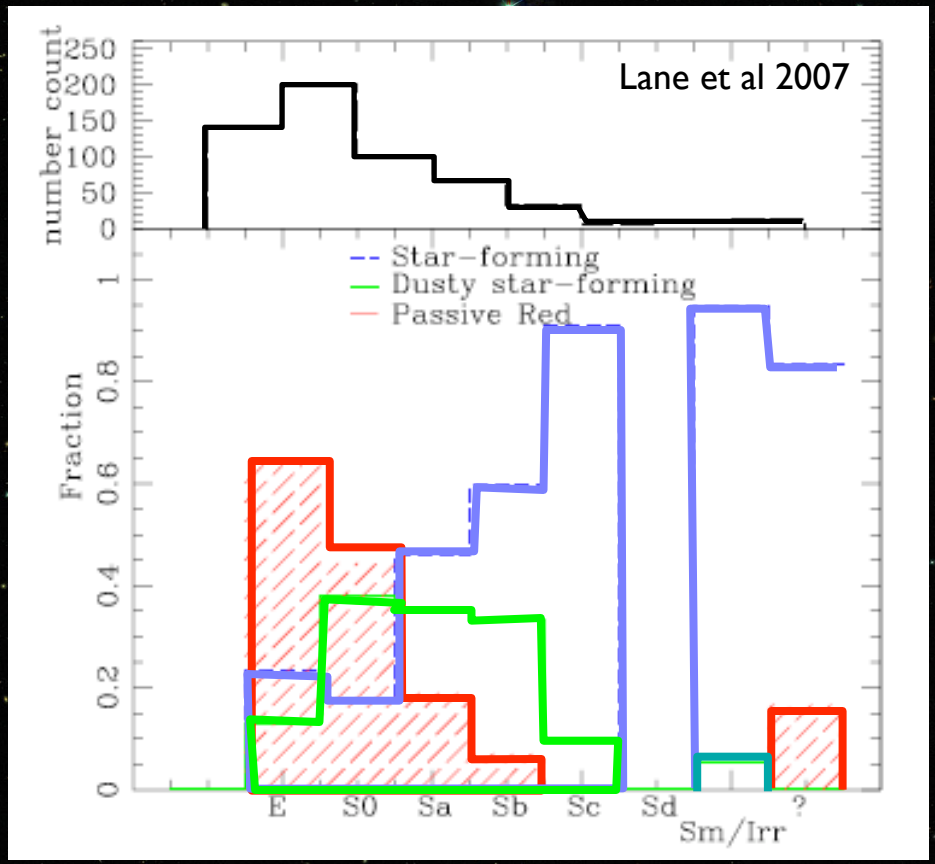
X-ray ultraviolet optical infrared radio

dust obscuration

Galaxy Classification



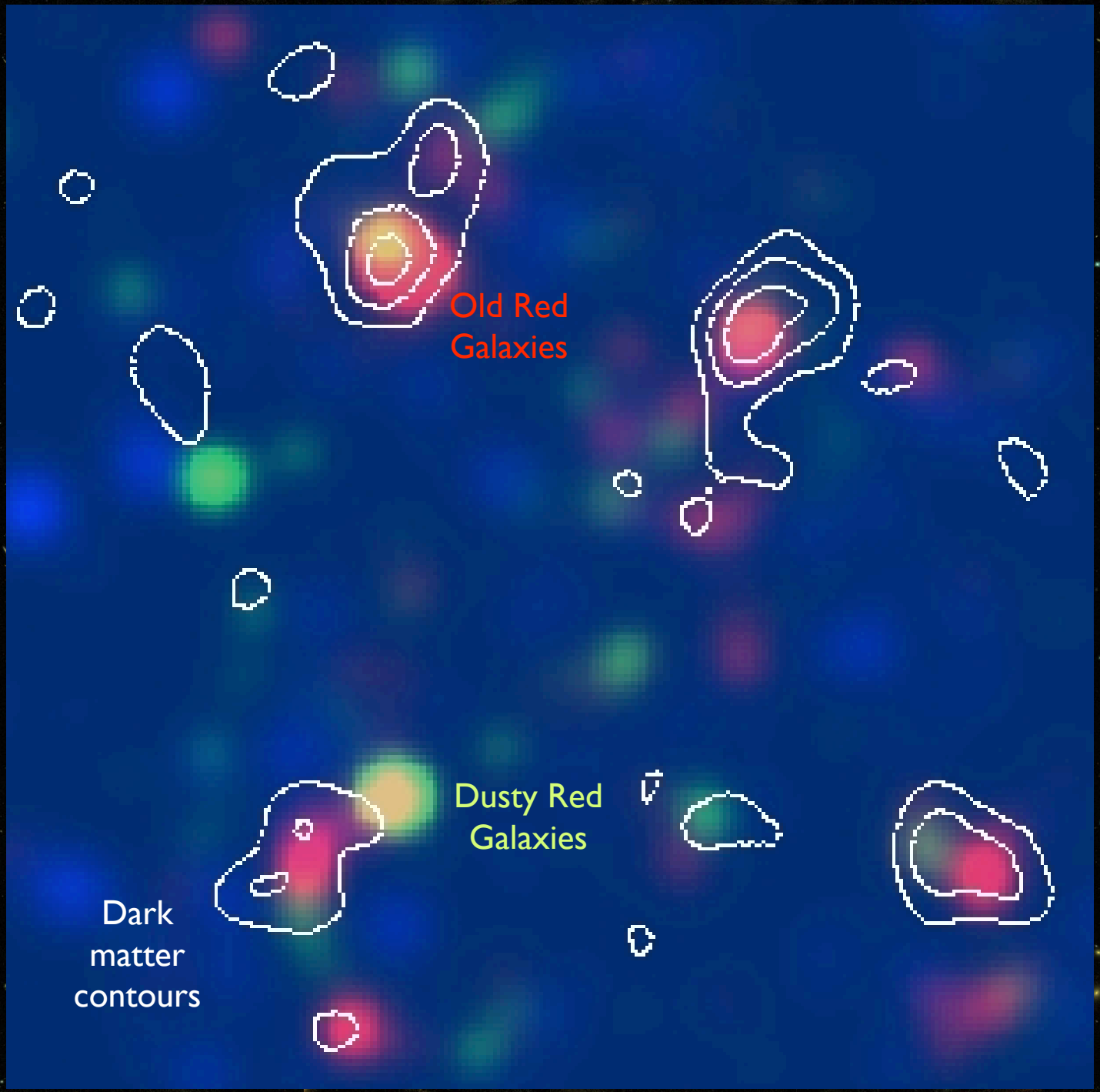
A large population of anemic spirals/dusty red galaxies



early-type late-type

A population of dusty red star forming galaxies make up 30% of the cluster red sequence

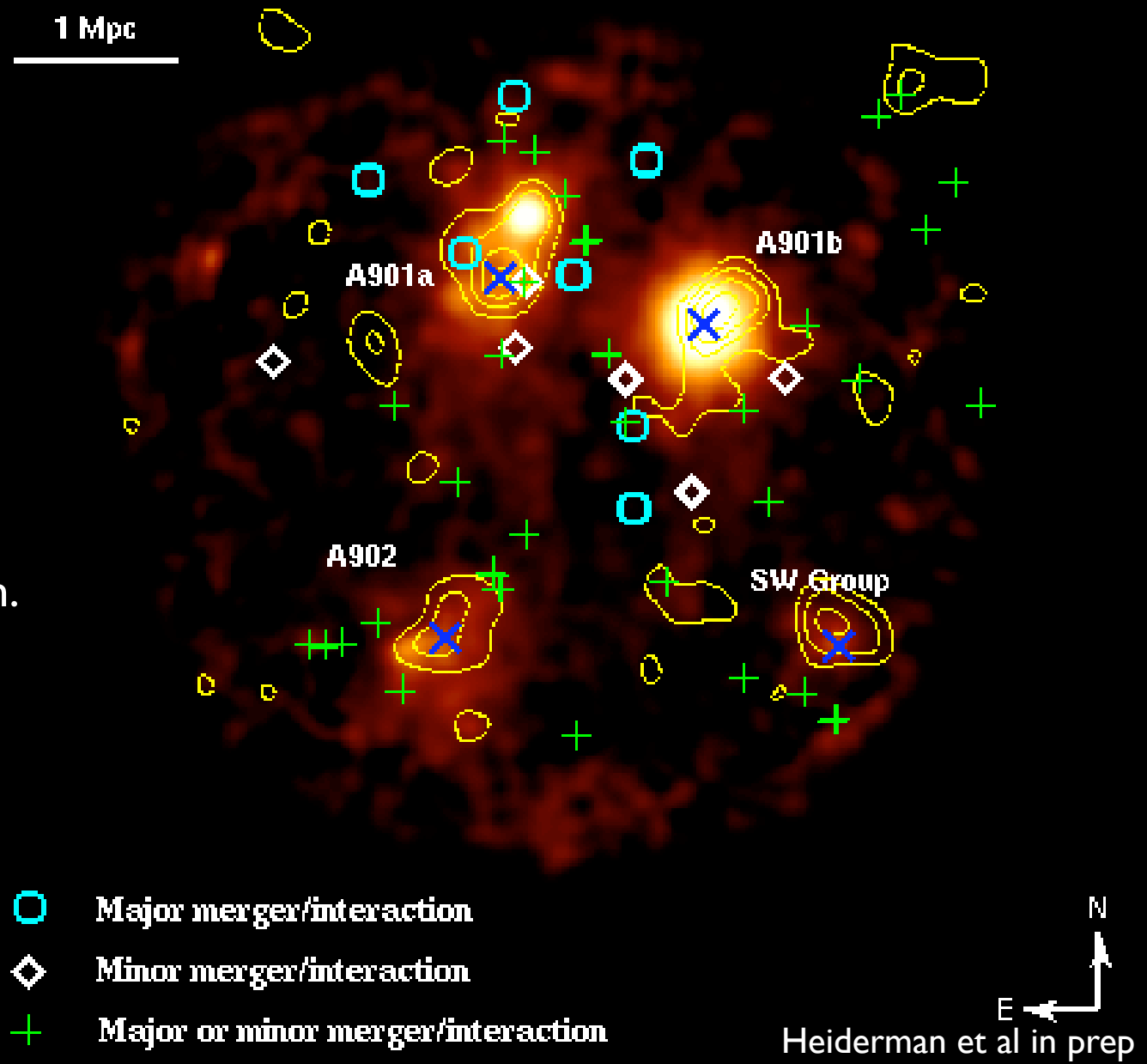
Step 3: connect galaxies and environment



Step 3: connect galaxies and environment

Result:

it is the intermediate density or infall regions where most of the signatures of galaxy transformation are seen.



Heiderman et al in prep

What causes galaxy evolution in dense environments? Preliminary conclusions:

- It's not the gas
- It's not high galaxy densities
- The action seems to be where galaxies are first experiencing the pull of dark matter
- Our first findings are showing a sweet-spot where galaxies become close enough, and are moving slow enough to interact and transform.

Summary

- STAGES is a multi-wavelength survey of the Abell 901/902 supercluster.
- The survey aims to distinguish between the different physical mechanisms which drive galaxy evolution in dense environments.
- Weak lensing analysis of HST images permits high resolution dark matter "observations".
- Old Red Galaxies trace the underlying dark matter distribution
- Intermediate density regions key site for galaxy transformations
- Current work bringing together all different multi-wavelength cluster information to form a coherent understanding of the violent history of this supercluster